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Metal Progress

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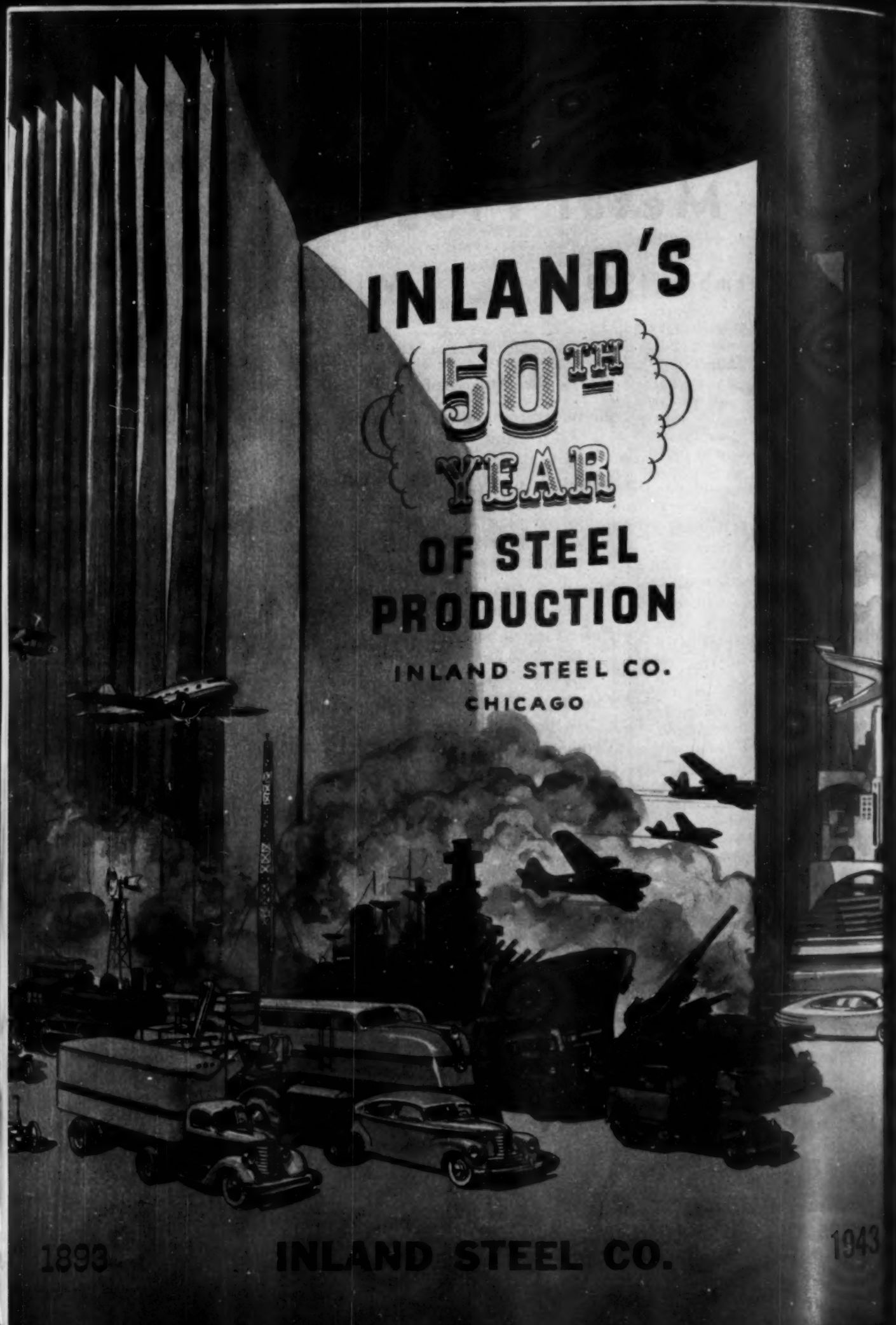
INLAND'S
50TH
YEAR
OF STEEL
PRODUCTION
INLAND STEEL CO.
CHICAGO
1893
INLAND STEEL CO.
1943

Manufacture of 20-Mm. Cartridges (Condition of Metal During Processing)

By L. E. Gibbs
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Revere Copper and Brass Incorporated

IN TWO ARTICLES (*Metal Progress* for June and August) cartridge brass has been discussed as an alloy of 70% copper and 30% zinc, and some general principles were stated which control its physical and other properties. To point-up these principles, the following article examines the processing of a 20-mm. cartridge case.

At the outset it might be well to state that all brass cases are processed in the same general way, but that individual characteristics of the various case designs will modify the sequence of production operations. At the same time, plant-to-plant production lines will vary because of differences in equipment available to do the job, as well as the personal preference of production staffs. For example, the extent of automatic handling tends to increase as the caliber decreases (as would be expected) particularly in feeding to presses and head-turning machines.

Regardless of these variations, all manufacture is concerned with cupping a disk of proper gage and grain size at the start and then, by successive draws and re-draws with appropriate anneals, elongating the original cup into a hollow cylinder with one end closed in a dome shape. A case which is short in length compared to its diameter will be done in two or three draws, and a long one in, say, five. The heading operations are nearly the same for most designs, and the neck will have either a gradual taper or a relatively sharp diminution (the latter exemplified by the 20-mm. case about to be described in detail). The head will be finish-turned — either for accurate size and contour when a lip is present (ammunition for non-automatic, large caliber guns, as an example) or, in addition, for an extractor groove in small caliber, semi-automatic ammunition. (The lip or extractor groove engages a finger which removes the spent case from the chamber.) Mouth annealing is required to produce metal soft enough for crimping onto the projectile; for protection against stress corrosion cracking (season cracking) a final relief anneal is used.

There is much similarity also in the physical properties of various sizes of cases. Details will again vary because of individual needs of different types of ammunition. Cartridge cases all act as containers for a primer plus a propellent charge and, in "fixed" ammunition, as holders for the projectile. The general properties demanded of the metal will vary in different parts of the case, but adequate strength to prevent bursting or similar failure is an elementary requirement, together with equally adequate elastic properties to return to shape after firing stresses are released. Sufficient ductility is needed to avoid brittleness.

Specifically, the body of the case must expand, by the pressure of burning powder, enough to take up the clearance between it and the gun chamber, thus sealing off gases from leakage back through the breech. This property is known to ordnance officers as "obturation". After the projectile has left the gun, and the case is ready to be ejected, it must return nearly enough to its former size so it may be removed freely and quickly. This requirement means an elastic limit sufficiently great so that permanent set doesn't occur upon expansion. The mouth must be at least strong enough to hold the projectile during the time of storage and transportation, and tightly enough not only to keep them together but also to protect the powder — yet at the moment projectile leaves the breech chamber the mouth should let it go without cracking.

There are other requirements which aren't part of the present discussion, such as elastic modulus, non-sticky surface when hot or cold and in contact with gun chamber, corrosion resistance for safe storage, proper size and tolerances. It

might be remarked, however, that tolerances are a particularly important subject, in view of the high order of interchangeability needed. Any one of millions of cases must fit any one of thousands of guns for jam-free operation. This explains the necessarily thorough gaging and inspection the Ordnance Department gives them. All in all, a cartridge case, though it may not be as spectacular as an aircraft engine, is in its own way a pretty precisely controlled engine of destruction.

Turning now to the manufacture of a 20-mm. cartridge case, the operations shown are not necessarily exact for any one manufacturer — for reasons explained previously — but are intended to show the overall picture. The layout of samples, as in Fig. 15,* is numbered by the piece; they are shown about one-third size. For the operations sequence, refer to Table IV, on the opposite page, but note that various cleaning operations are not listed. Micrographs are at 75 diameters.

Referring particularly to the layout in Fig. 15, it will be noted that the cupping and first three draws serve generally as preparatory operations. The finished case has a light wall gage, compared to the original blank thickness. Since a relatively large mass of metal must be provided at the head, the original blank must be of sufficient size to do this. Consequently, these preparatory operations are not elongating the part much, but are rather thinning the side wall of the "cup", and retaining the heavy base needed to finish the head.

There is, necessarily, a limitation on the reduction that can be made on the wall's thickness with each operation, not only because great reductions make metal considerably harder and

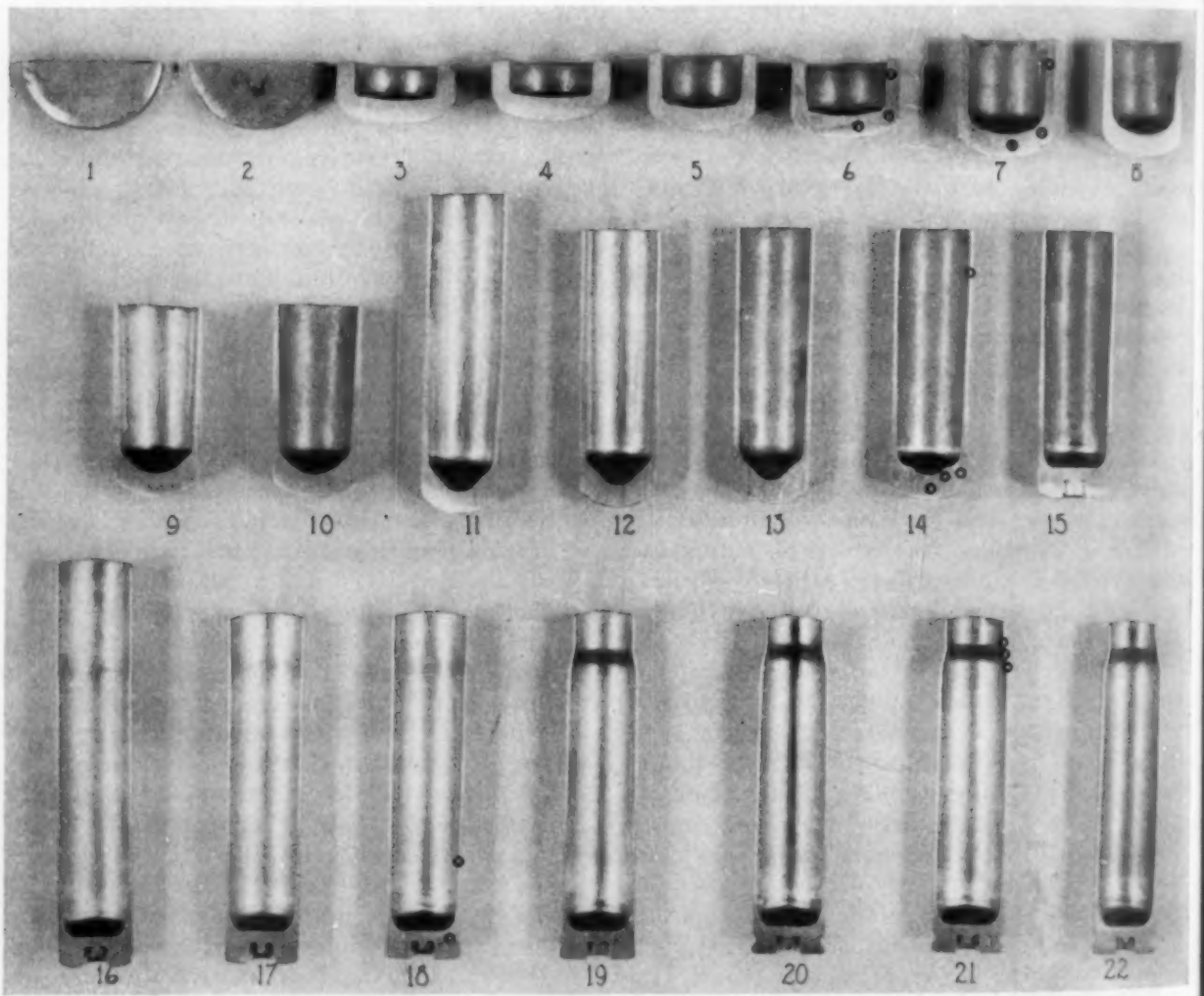


Fig. 15 — Various Stages in 20-Mm. Case Production, as Listed in Table IV. Locations of micros in this article are shown by small circles

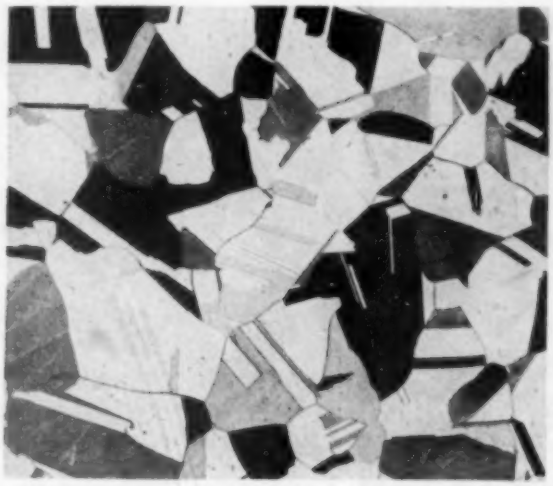
*Figures and tables are numbered consecutively with illustrations in former installments.

ductility drops, but because the tools also have some limitations. The 20-mm. case takes a greater number of initial draws before pulling out to length than do some of the larger calibers with smaller ratios of height to diameter. Also, more metal is needed at the base for the peculiar head design.

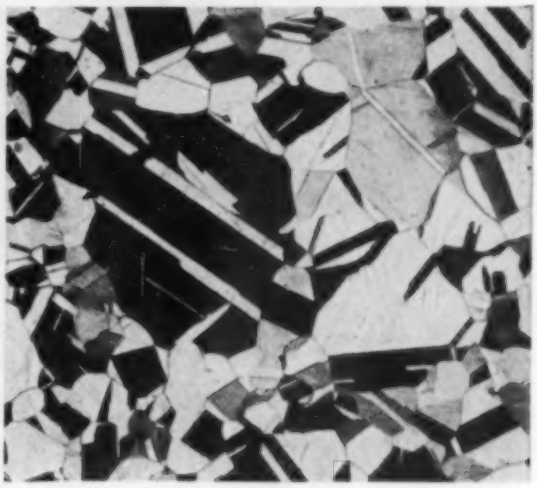
The fourth and fifth draws pull the length out to that required to produce the finished case, allowing for adequate trim. Re-striking and indenting operations No. 14 and 15 are again more or less peculiar to this cartridge and are tied in with the head design. Metal doesn't always flow as predicted, and die shapes many times must be varied on the job to produce the flow which later will give the finished contour needed. At the same time there are physical property requirements of the head which often necessitate additional operations; otherwise, the amount of cold working would be so slight as to leave the metal in nearly the annealed condition. (See further discussion on micrographs.)

16-W; Side wall

Fig. 16 — First Draw Annealed; Step No. 6 of Fig. 15. Metal has characteristic large grain sizes (approx. 0.120 to 0.150 mm.) with typical twinning. Magnified 75 diameters



16-B; Center of base



16-C; Corner of base

The tapering operation No. 19 in this line-up reduces the diameter of the case, but some cases are truly tapered without the sudden "necking down". The latter operation may be accomplished without an internal mandrel or punch, which is used on the regular draws.

(Punches, for the first to third draws, will usually be roughed at the end by grooving or other means so metal will not flow readily sidewise under them. The base of the cup thus stays thick. Dies and general tool design are matters for discussion which, though exceedingly important when it comes to performance of a metal, are not without considerable individual opinion and will not be expanded upon at this time.)

Heading may be done in one operation on a one-stroke press, or with a dial feed with all of the accessories to do the entire job, including the marking of caliber, manufacturer, number, date, and so on. Such may be done even on cases as large as 5 in., using, of course, tremendous

Table IV — Sequence of Operations

Samples No.	Operations
1 and 2	Blank; anneal
3 and 4	Cup; anneal
5 and 6	First draw; anneal
7 and 8	Second draw; anneal
9 and 10	Third draw; anneal
11 to 15	Fourth draw; trim; anneal; re-strike; indent
16 to 19	Fifth draw; trim head; neck anneal, taper
20	Machine extractor groove
21	Mouth anneal
22	Finished case, stress relieved

presses. Final machining may include drilling the primer hole, though not shown in Fig. 15. In some types of ammunition this is followed by drilling and tapping inside the head for subsequent insertion of hooks for powder bags.

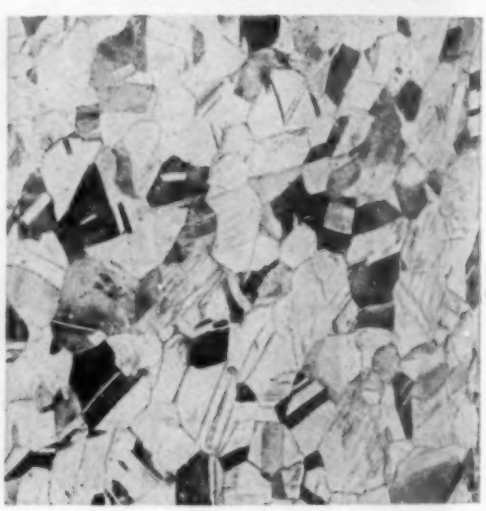
While cleaning is not strictly a branch of metallurgy, it should be mentioned that best drawing requires clean surfaces. Drawing compounds which carbonize at annealing temperatures, such as certain oils or soaps, should be removed prior to heating. Such carbon products are very nearly impossible to remove, once on, and are destructive to tools. Cleaning of surface oxide after annealing is obviously necessary, and the solvent must be of a type to leave unetched surfaces, etching being one cause of metal breakage, for the surface friction, die-to-work, becomes too great.

In the course of a study of 20-mm. case fabrication, each of the samples in Fig. 15 was examined for micro-

17-W; Side wall having severely cold worked crystals

Fig. 17 — Second Draw; Step No. 7 of Fig. 15

17-B; Center of base, showing no evidence of strain lines or deformation, hence no cold working of any consequence except perhaps at the very surface of the metal



17-C; Corner of base, showing slight evidence of strain lines

structure. Since the photomicrographs of some sections are practically identical with others, certain typical ones will be shown here. The blank, cup and first three draws show generally similar grain sizes. This blank was annealed, but many cases, especially for small arms, are blanked and cupped without annealing. Grain sizes for these rather drastic initial operations are kept large — 0.090 to 0.150 mm. on the average, and for reasons developed in the two articles already published. Large grain sizes would be expected since "orange peel" is of no matter; no subsequent surface polishing and maximum ductility is wanted during these intermediate operations. No hold-downs are employed in drawing, so danger of breakage is not present due to this cause.

Typical of conditions existing during these operations are micros of the first draw annealed (Fig. 16-W, C and B) and the second draw (Fig. 17-W, C and B). On the second draw sample the wall (Fig. 17-W) shows typically cold worked structure, but the base shows no deformation of any consequence. Both of these are typical of samples up to and including fourth draw. The wall tends to have a smaller grain size than the base. In view of what was said in the earlier articles, this is to be expected since recrystallization requires previous cold working or, contrawise, it was stated that grain growth does not occur at all readily upon re-annealing. We have the latter condition in effect here because the base has not been cold worked. The corners are lightly cold worked, since some flow occurs at the junction of the punch radius and punch side.

The base of any case must be formed to the final shape desired, as well as have strength

enough to stand operating pressures and to hold the primer tightly. The base of this case is cold worked by the several indenting operations, along with re-striking. In Fig. 18 the side wall corner and part of the base show annealed structure, since cold working after the last anneal has been confined to only part of it.

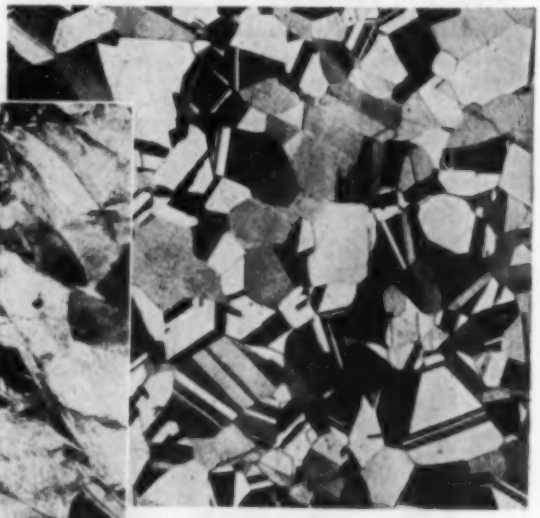
As compared to this, refer to the micros of Fig. 19 showing the condition of the base after all of the cold working operations have been performed on the head and side wall. The side wall and a greater portion of the base structure are now typically cold worked in appearance. The last or fifth draw must provide enough cold work in the side wall to raise the tensile strength and elastic limit up to the specification established by the Army or Navy according to the particular needs. This is an illustration of prior discussions, and the physical property curves in which we pointed out that increasing the cold work (by the reduction in area or B&S numbers) is the only way to increase the tensile strength of non age-hardening copper-base alloys. The micrographs quite graphically show also the varying structures typical of the varying amounts of cold working.

Fig. 18 — Fourth Draw, Restruck; Step No. 14 of Fig. 15

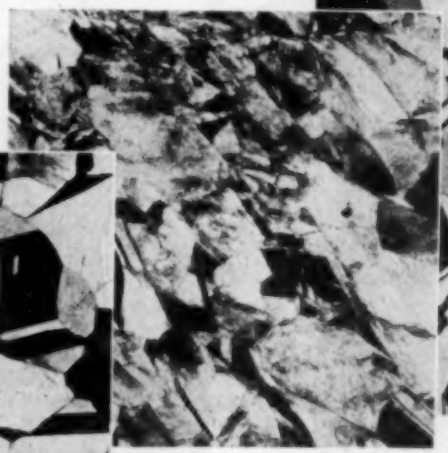
In order to reduce the diameter at the mouth of the case, a cold working operation known as tapering is used. However, the case wall may be cold worked already to a degree such that there is not enough remaining ductility to permit the shape change. A prior neck anneal is then used for only such portion of the open end as will be affected by the reduction in diameter.

Following this tapering to size, the mouth is annealed — perhaps by gas flame or salt bath — an operation usually designed to produce a very small grain size. Such a small grain size is indicative of metal with considerable ductility, yet when it is cold worked by crimping onto the projectile in the shell loading plant, the strength is sufficient to hold tightly. Even if more severely cold worked metal would turn over without cracking, there are instances in which it would be of no value. For example, the elastic limit might be so high the amount of movement during crimping would not be enough to permanently deform it — there is some "spring back". Figure 20, showing micros made after the neck anneal, taper and mouth anneal, indicates

18-W; Side wall not worked, has annealed structure, grain size about 0.100 mm.



18-C; Corner of base has same structure as side wall



18-S; Shoulder on inside; crystals are distorted by restriking operation which hits only part of the base

18-B: Center of base, has annealed structure, grain size about 0.150 mm. average

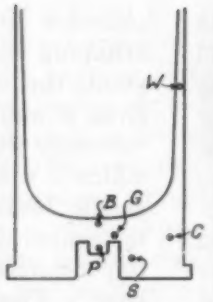


Fig. 19 — Fifth Draw, Headed; Step No. 18 of Fig. 15. Sketch shows location of micros

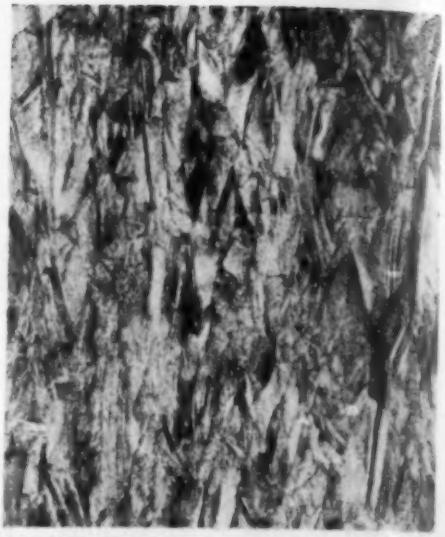
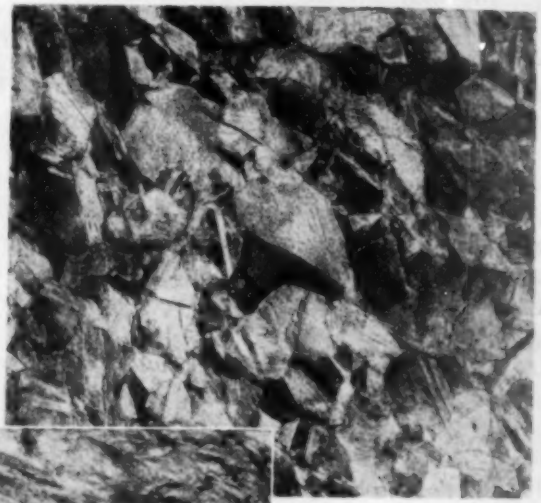


Fig. 19-W (at left); Side wall, extensively cold worked

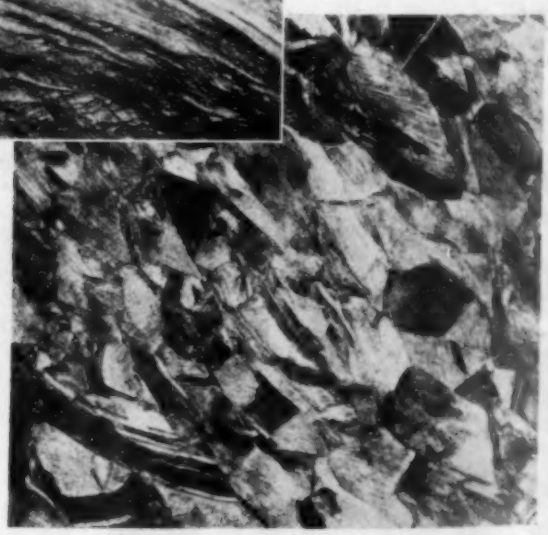
19-C (right, below); Corner of base has received some cold work and shows a large number of strain lines but not much deformation

19-B (above); Center of base has been slightly deformed and shows a few strain lines



19-G (right); Groove; severely cold worked; considerable flow of metal is typical

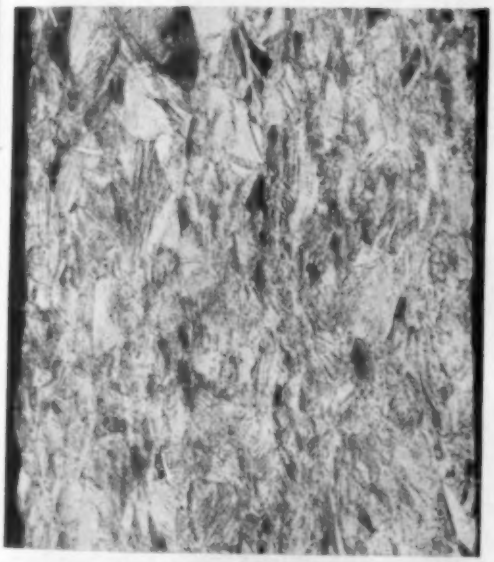
19-S (below); Shoulder is cold worked; some evidence of directional flow



19-P (left); Shows range of conditions in pimple, from no cold work at end to very severe cold work at neck

Fig. 20 — Structures at Mouth and Neck of Finished Case; Step No. 21 of Fig. 15

20-M; Mouth has very fine crystal size, less than 0.015 mm. Prior to mouth anneal, it was identical in appearance to 20-N



20-N; Neck is cold worked, typical of average reductions

20-S; Shoulder is slightly cold worked (typical micro)

what has happened. The mouth (Fig. 20-M) is now very finely recrystallized, though prior to mouth annealing it was cold worked, like the next lower section (neck, Fig. 20-N). Finally, at the shoulder (Fig. 20-S) strain lines across the crystals indicate light cold working — in fact so light that the grain size resulting from the neck anneal could readily be determined.

The final operation of relief annealing does not change the crystal structure, and any micrographs in figures relating to the fifth draw or mouth anneal are duplicated by those taken on the finished case.

In summation, the mouth is left in a lightly annealed state (0.015-mm. grain size range in Table II of the June article), the side walls cold worked to a considerable degree and parts of the base are still soft but other parts of the case are severely cold worked.

Tensile Impact of Carbon Steels

A PAPER entitled "Some Tensile Shock Properties of Carbon Steels", by F. V. Warnock and J. B. Brennan for the October 1943 meeting of the British Iron and Steel Institute, describes precise equipment for measuring tensile impact, or "shock properties" as the authors prefer to call it. One end of the ¼-in. diameter specimen is locked into a 7-lb. tup, and the upper end into an arresting crosshead. The combination is dropped vertically and the crosshead strikes a massive anvil. Residual energy remaining in the tup after fracture of the test piece — always a difficult item to determine accurately — is measured by a spring-balanced dynamometer into which the tup falls.

Previous repeated-blow tests had indicated that when the number of blows to fracture was plotted on double-logarithmic paper against height of drop, the result was a straight line — at least as far as ten blows. In this way a check is had on the accuracy of measurement of the residual energy in the tup after single-blow fracture. A series of tests at varying heights of drop, each one more than sufficient to fracture the specimen, gave rupture figures with mean deviation of ± 2%.

A series of basic carbon steels ranging from 0.12 to 0.63% carbon (other elements quite constant) were tested both by shock and static tension in as-rolled condition. Breaking energy in the tensile test was computed from the area under the stress- *(Continued on page 976)*

Marcus A. Grossmann

Researcher in Steel;
Newly Elected President
American Society for Metals

Notable

PROBABLY one of the most remembered and talked of chapter meetings in the history of the American Society for Metals was in Chicago in May 1934. Scheduled celebrity for the evening was Dr. T. Holland Nelson, who was to talk about stainless steel. Imagine Dr. Nelson's astonishment upon receiving a copy of the notice of the meeting to discover that, in spite of his international reputation as an authority, the Chicago Chapter had unbeknownst to him arranged for another expert to share the spotlight. The new speaker was none other than Professor Ias, Swiss scientist from the University of Vitznau, who was in Chicago to visit the Century of Progress Exposition.

When the meeting began, it was Professor Ias (first name Anan), be-whiskered and be-medalled, complete with frock coat and gorgeous red sash across his white shirt front, who was called first by Chairman Walther Mathesius. In an accent thick enough to cut with a broadaxe, the Professor began by showing beautiful authentic slides, illustrating scenes in his home town. Then, as some members laughed, while others deplored this discourtesy to a distinguished foreigner with unfortunate accent, he swung into his discourse on stainless steel. As the slides were shown, strange things happened. Charts performed as no charts ever had before; physical properties took strange and temperamental quirks; fact, error and mythology emerged in a guttural jargon that quickly reduced the audience to a mild state of hysteria.

Perpetrator of this profound scientific double-talk was Marcus A. Grossmann. Ruefully, he will tell you that to this day more people remind him of Professor Ias' brief talk than they do of any of the dozens of serious lectures he has delivered before chapters all over the country.

To succeed in delivering a burlesque of a scientific talk before a group of technicians requires considerable proficiency as a public speaker. Dr. Grossmann's speaking ability, as attested by his many addresses and lectures, and high-lighted by Professor Ias' brief emergence from cloistered obscurity, illustrates one of the characteristics which lie behind his solid accomplishments. For Grossmann was not always an accomplished, or even a fair, public speaker. But when he discovered that lucid verbal presentation of a subject was necessary to pass on knowledge gained from research, he set out to acquire that ability.

Dr. Grossmann's writings, like his lectures, are noted for their clarity and simple understandable style. ["Amen!" sayeth The Editor.] This talent, like his speaking ability, is strictly acquired and not native. Since he found that writing ability was as important a tool as public speaking, he determined to learn to write in such a manner that he could not be misunderstood. Prior to that time his sole contribution to literature had been a resounding flunk in College English. How well he has succeeded in changing this state of affairs is illustrated by his extremely popular "Principles of Heat Treatment", and his early translation of Heyn's "Physical Metallography", as well as his many papers on metallurgical subjects.

There was a time when he was not certain that he cared to continue in the study of metallurgy, let alone learn how to transmit facts about it to others. Born and raised in Youngstown, Ohio, the lure of the steel mills got him early in life, so that when it became time to acquire a higher education, he forsook the theological paths of his cleric ancestors and chose M.I.T. and metallurgy under Professor Hoffman. By the time he reached his third year, he was not sure that he would like to be a metallurgist. The lure of the whist tables in the Union greatly outweighed that of the scorifiers and pyrometers. Marc's marks suffered accordingly. It was not until a parental ultimatum of "study or get out and earn your own living" that he bore down on the scholastic rather than the social aspects of college life. The results were startling to all the Grossmanns and the teachers, for graduation time found him with honor standing.

Upon graduation he spent a year as a laboratory assistant at M.I.T. before embarking on his industrial career as chemist and metallographer with the Pittsburgh Laboratories. That was in 1912. Three years later he joined the

Vanadium Corp. of America, where he made his first research discovery. It was relatively simple, but it came to him as he was reading a technical journal about some British work. Suddenly he realized that this paper on a different type of steel gave him the clue to help with a problem which was troubling him.

The impetus of this first accomplishment, plus the nature of much of the work which came his way during his days with Vanadium, re-oriented Grossmann's ambitions in the direction of greater emphasis on "pure" research. During college days his inclination, although not too well defined, had been to become a steelmaker, and he intended to apply his technical education to steel works practice. Now, confronted with specific problems, he came to see that one could not well study the effects of a single element on the properties of steel without determining the effects of all alloys in its composition.

America's entry into World War I, however, interrupted this tendency, and from 1917 to 1919 he was entirely concerned with practical application of research to armament production, serving as chief of the heat treating section in the metallurgical division of the National Bureau of Standards. In 1919 he returned to Vanadium Corp., leaving a year later to become chief metallurgist of Electric Alloy Steel Co. of Dunkirk, Pa. It was during his four years with this organization and its affiliate, Atlas Steel Corp., that he first became acquainted with Edgar Bain, then studying the intimate facts about tungsten wire for General Electric Wire Works at Cleveland. This acquaintanceship with Bain, and their mutual interest in toolsteels, resulted in their collaboration in writing the book "High Speed Steel", published in 1931 and still a standard reference work on the subject.

Continuing to advance in his chosen field, Grossmann in 1924 became research metallurgist for United Alloy Steel Co., of Massillon, Ohio, remaining with it as that company merged with Central Alloy Steel Corp., which, in turn, became part of Republic Steel Corp. Although he had previously spent three months in Europe in 1923, it was during his seven years with United, Central and Republic that he learned most about Europe while making eight trips across the Atlantic to keep abreast of continental steelmaking methods and metallurgical advances.

During this time he decided to pursue advanced studies under Professor Sauveur at Harvard, where, in 1931, he received his Ph.D. after completing a thesis on "Oxygen in Steel".

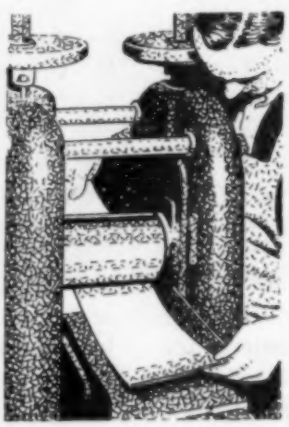
In 1931 Grossmann joined Illinois Steel Co. at South Chicago as a research engineer, and has remained with United States Steel Corp. subsidiaries since that time. In 1935 he became director of research for Illinois Steel Co., and upon the formation of Carnegie-Illinois Steel Corp. was made Director of Research for the new organization.

During these latter years, the new president of the ⊜ has striven more and more to strike a 50-50 balance between primary fundamental research and practical application, for he has been convinced that only through such balance can the researcher contribute most effectively to industrial and social progress.

During these years, too, he has achieved major recognition of his accomplishments, including the 1930 Campbell Lectureship of the ⊜ on "Oxygen in Steel". He also received the Howe Medal with M. Asimow and S. F. Urban for the paper on "Hardenability and Quenching, and Some Quantitative Data" in ⊜ *Transactions* in 1941, and the Hunt Gold Medal of the A.I.M.E. in 1943 for the paper on "Hardenability Calculated from Chemical Composition". These papers, in addition to being notable contributions of important knowledge, have inspired much further work by other researchers.

World War II, like World War I, has found Dr. Grossmann devoting his time and talents largely to practical application of metallurgical research to armament production. In addition to his work for Carnegie-Illinois, he is consultant on the staff of Frankford Arsenal, and is active on more than a dozen important wartime scientific committees of the government and national technical societies.

A few added personal notes should include the facts that he was chairman of the Buffalo, Canton-Massillon and Chicago chapters ⊜, national trustee 1939-1941, and vice-president in 1942. He is a member also of the British Iron and Steel Institute, American Institute of Mining and Metallurgical Engineers, American Society for Testing Materials, and American Iron and Steel Institute. Aside from his vocation, his interests in fields of science, art and public affairs are wide and varied, but transcending them all is his pride in his talented wife, Patricia Berkson Grossmann, whom he married in 1935, and their daughter, Linda. E. C. LOGELIN



Basic Electric Steel Practice
as defined in a meeting of experts

ENCOURAGED by the success of the Annual Openhearth Committee meetings, the American Institute of Mining and Metallurgical Engineers has organized a similar Electric Furnace Steel Committee and held its first meeting in Pittsburgh early in October. The occasion was warranted by the three-fold expansion in furnace capacity since 1940, R. L. Baldwin of National Carbon Co. conservatively estimating that the capacity now existing is 2 million tons of acid steel in relatively small foundry furnaces, and some 6 million tons of basic ingots in rather larger steel mill electrics. Such an expansion means that a large number of new melters and helpers must be trained and the skilled men and supervisors spread very thin. Likewise it is posing some serious economic problems as to ultimate survival in competition with openhearth or converters. All these circumstances warranted the registration of 400 men, who sat through gruelling sessions to the very end. Credit is due to Charles W. Briggs of Steel Founders' Society of America as Chairman of the Steering Committee, Harry W. McQuaid of Republic Steel Corp. as Chairman of the Executive Committee, and Frank T. Sisco of the A.I.M.E. staff, for organizing a successful program.

The meetings followed the technique found so successful in the Openhearth Conferences, where a general topic was introduced briefly in a prepared paper, and the chairman would then call upon various experts in the audience for comment and personal experiences. Frequently the matter was complicated by the fact that one commentator would speak of good practice on a small 6-ton furnace and another on a large 70-ton furnace; other operational problems obviously differ as to whether the furnace is melting S.A.E. steel, stainless steel, or toolsteel. Consequently this reporter, at least, frequently felt the need of a summarizer who could point out the reasons for the divergent recommendations, or state the consensus. . . . .

Since a 70-ton unit is now spoken of as a "standard" steel making furnace, it is apparent that the material-handling problem looms large. Frank W. Brooke of Swindell-Dressler Corp. cited one year's parallel operation of two medium-sized furnaces in the same shop, wherein steel from the hand-charged furnace cost $3 per ton more than from the top-charged one. On the large furnaces, however, the necessity for proper placement of light and heavy scrap, ore and lime, requires charging machines of the openhearth type, and large charge doors. One operator said that the standard openhearth charging bucket should be discarded for one designed more particularly for electric furnaces.

Electrical Auxiliaries

Such large units also require particularly large electrical auxiliaries. While they remain essentially the same in nature as those installed 30 years ago, they are much more rugged and have been refined greatly in detail and design. Nevertheless electrical men and furnace operators are united in their dissatisfaction with this, that or the other feature. Samuel Arnold of American Bridge Co. pointed out that the most rapid melt required a steady energy input at highest power factor, yet the control board usually metered the amperes drawn from the supply lines, and the furnace operator then had to be an electrical engineer as well as a metallurgist to judge the conditions at the arc. H. R. Stansel of General Electric Co. also spoke up for a rotating type of regulator, much used abroad, or an analogous electronic device giving stepless automatic power regulation (voltage at the electrodes is changed only in major steps by taps on the transformer). It is obvious that if such a device can insure *constant* power input it will make for faster furnace operation than one where the power is widely fluctuating.

To this reporter it would seem that the main electrical equipment and auxiliaries supplied to a large furnace have become inordinately complicated and expensive — even though the elec-

trical engineer may give a good reason for each addition. Simplification would be a distinct step in advance. Fundamentally and electrically the high frequency induction furnace may be no simpler than a three-phase Heroult arc furnace, but who would think of picking up a 2½-ton arc furnace and using it as a pouring ladle? Yet F. T. Chesnut of Ajax Electrothermic Corp. showed some pictures of a large battery of induction furnaces melting gun steel, each heat being poured into a centrifugal mold and making one excellent barrel for a large caliber gun — and the entire plant operated by women! Metallurgically the induction furnace is handicapped by being a pure melter and must therefore have a selected charge. (This is of course an advantage in avoiding carbon pick-up when remelting stainless steel scrap.) Likewise analytical and inspection problems loom large when each step must be repeated for each small heat.

Refractories

Finally as to refractories: R. P. Heuer of General Refractories Co., and Frank J. Vosburgh of National Carbon Co. gave notable talks on the general improvement in brick and electrodes. The roof, rather than sidewalls or bottom, is the critical part of the structure, and it is surprising that a silica brick roof is endured on a basic-lined furnace. The extra cost of a basic roof may well be repaid by its longer life and resistance to iron oxide spatter during the melting stage. (Hot metal charges should also cut down damaging temperature fluctuations.) Due to the non-conducting nature of firebrick, it is apparent that water cooling — whatever good effect it may have in keeping the outside of the furnace cool — will not reduce the temperature of the inner face until the wall has wasted away nearly to the cooler. The only palliative which received a good hand by operators was the plastic refractory which can be shot into the furnace with air guns; it really sticks to hot roofs and renews their surface.

Melting Poor Scrap

Turning now to the melting operation, everyone agreed that all furnaces, both acid and basic, are making good steel from very bad scrap — almost impossible scrap in the old sense. One operator cited a 10% drop in production when a considerable portion of dirty turnings was forced on him. Adolph J. Scheid ⊖ of Columbia Tool Steel Co. gave a general picture of scrap "segregation" in his remark that 40% of the "toolsteel scrap" received by his firm analyzed outside of that classification, and that 10% of so-called high speed had no tungsten in it. Yet properly segregated scrap really is worth money to electric melters. Wm. J. Reagan ⊖ of Copperweld Steel Co. said that if scrap is really segregated, the oxidation period can be greatly reduced, for the melt-down analysis can be predicted and the bulk of the alloying elements for the low alloy steels recovered as residuals. He estimated $4 to $5 per ton as the value of these items. Unfortunately most mills receive doubtful and bulky scrap, and no heavy stuff except own ingot butts or bloom crops, so it is almost impossible to get enough metal into the furnace for one heat without the very objectionable "re-charging".

Melting and oxidation merge into each other. A definite oxidizing period was unknown in the early days of electric steel, although it is now commonly believed that it has far more influence on basic steel quality than the mere elimination of phosphorus and surplus carbon would indicate. (Note the 45-min. carbon boil required by gun steel melters at Sorel, emphasized in "Critical Points" for September.) Its specific functions are said to be five: *(1)* Convert phosphorus to oxide and absorb it into a basic slag, reactions that occur best at a moderate temperature, early in the heat; *(2)* stir the charge and avoid a cold bottom — that prolific cause of inferior steel; *(3)* bring carbon to the correct amount (while so doing silicon must also be oxidized); *(4)* wash out hydrogen; *(5)* make little inclusions into big ones — big enough to float out — by bringing them into physical contact. Iron oxide is the reagent for these chemical actions and carbon monoxide for the physical stirring; 30 lb. of oxide may be expected to be formed per ton of heavy scrap melted, 80 lb. per ton of country scrap, and 100 lb. per ton of light scrap. Balance of the required iron oxide is charged as clean roll scale or lump ore, both low in sulphur and silica. Magnetite ore is an excellent source of oxide. Chateaugay concentrates being almost chemically pure Fe_3O_4. Divergent preferences were shown for limestone and for burned lime in the charge; some felt that the CO_2 from limestone would help in the boil, while others believed that electric heat is too expensive to use in burning the stone, and that CaO had a quicker effect on the slag. Wm. B. Arness ⊖ of A. M. Byers Co. emphasized the necessity of charging oxide no nearer than 1 ft. from electrodes, else they would be chewed up rapidly. Alex L. Feild ⊖ of Rustless Iron & Steel Corp. expressed the great importance of a really *dry* charge if trouble with hydrogen is to be definitely avoided; at his plant everything that

goes into the electric furnace except scrap and ferro-alloys is put through a rotating kiln and heated to a dull red.

Wide variation in the relative amounts of ore and lime charged were noted. Gilbert Soler of Timken Steel and Tube cited experience with arc furnaces ranging from 1 to 100 tons capacity, and said that oxide charges should be varied with size of furnace, nature of scrap and analysis of steel being produced. Harold E. Phelps of Rotary Electric Steel — famous for fast production of aircraft steels in 65-ton heats from pretty terrible scrap — charges 8% of ore and 3½% lime, both close to the bottom and distant from electrodes. Enough carbon is in the charge — even for high carbon steels — so that 50 points (10 lb. per ton) is boiled out before blocking the heat. The amount of ore runs up to 15% for low carbon melts, analyzing say 0.06% at slag-off for a 0.12% carbon carburizing steel. Another factor mentioned is that a minimum of ore and slag volume will give a maximum recovery of alloys, but this has its hazards for it tends toward cold bottoms and dirty steel.

Oxidation Slags

Karl L. Fetters of Carnegie Institute of Technology gave an excellent exposition of the nature of a desirable slag to be shaped up after this melt-down period. He regarded a minimum weight to be 2% of the bath, as compared with 10% for an openhearth heat. Basicity varies greatly, plant to plant, lime to silica ratio being 0.7 to 4.0, although a ratio of 2.0 or 2.2 appeared to be optimum for carrying off phosphorus and sulphur while reducing the silicon practically to zero and leaving behind as much manganese and chromium as possible in the metal bath. A lime-silica ratio of 1.75 may be associated with a residual phosphorus of 0.03; a ratio of 2.5 will bring phosphorus below 0.01%, other things being equal. Generally speaking, electric furnace slags contain more MgO from the banks than openhearth slags do, the manganese is lower because pig iron is seldom charged, and phosphorus is usually lower. They also are better "shaped up" — shop term meaning a nearer approach to equilibrium conditions. Iron oxide content depends inversely on the carbon in the steel at the end of the boil; it can be lowered by dipping electrodes in the bath, and raised by adding ore.

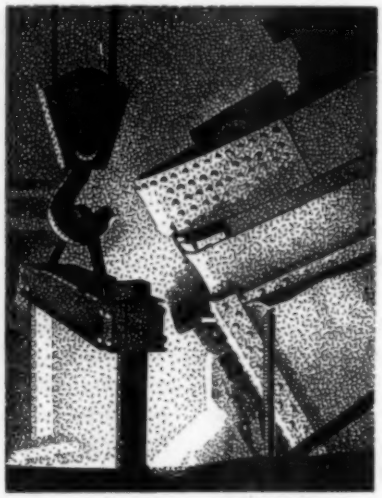
Ray J. McCurdy of Republic Steel Corp. said that melters can judge slag pancakes to good advantage, as in openhearth practice, except that the basicity ratio should be judged a little higher. In other words if the slag (by openhearth experience) would be judged 2.0, it actually will be 2.2 or 2.3 by chemical analysis. When the furnace men understand this and use such tests regularly, second slag-offs are practically never necessary.

Deoxidation Period

Harry McQuaid gave the reasons for the next stage in electric steel melting as a logical sequence of the oxidation stage. In the first part of the heat the metallic bath is filled with reactive iron oxide; in the second (refining and deoxidizing stage) this iron oxide must be removed — as well as other metallic oxides present. A good start is by "reboiling" with ferromanganese or spiegel. The iron oxide in the metal is reduced by manganese, and the manganese oxide formed will combine with silica. If temperature is high enough (and this is extremely important) the alumina and manganese silicates can liquate to the slag. Such deoxidation by manganese is temporary, for the metal is still covered by the oxidizing slag, and this is therefore skimmed. Practically all the manganese can be added just before slag-off without more than 20% loss, a practice

followed by some melters with very good results. In some other plants the main manganese addition is made *after* slag-off.

McQuaid is a strong believer in adding the manganese immediately after slag-off, as well as some strong deoxidizing agent (aluminum or Si-Al-Ca combinations). This will reduce oxygen in the metal to such a low point that the slag will shape up quickly and all other major alloying additions can be made immediately. Ingredients for the final deoxidizing slag, already mixed, can be rapidly shovelled in, melted, and "used as a blotter to mop up the rising oxides". (Considerable difference of opinion existed as to the proper order of adding alloys, but no very logical reasons were presented except by B. H. Brown, of Jessop Steel Co., who likes to add chromium at the very end, after the final silicon, so there may be no chance of loss by oxidation.)



Refining Stage

Carbide slags are very popular for this stage. Henry C. Bigge of Bethlehem Steel Co. cited the following, used on 75-ton heats of S.A.E. 3312: 2100 lb. lime, 300 lb. 80% ferrosilicon, 375 lb. spar, 150 lb. powdered coke. Other speakers said they like to get as much lime in as possible and still have a fluid slag; total slag weight of about 2% of the bath seems to be a satisfactory average. Frequent small additions of powdered coke or ferrosilicon are necessary to keep this slag well deoxidized.

One of its important functions, of course, is to absorb sulphur, of which perhaps only one-quarter has been taken off in the oxidizing slag. The exact mechanism of the sulphur reaction with calcium carbide is unknown; Reagan mentions that now and then a heat is encountered where sulphur remains stubbornly constant. In such cases it is better to slag off and make up a new carbide slag. Sulphur elimination, as well as final deoxidation, depends on action or movement in the bath — not an easy thing to get in the quiet bath, absorbing low power.

Phelps judges the condition of the slag by iron oxide analyses. When this is reported at 0.5%, perhaps 20 to 25 min. after it is completely melted, he adds enough ferrosilicon to bring the metal to required analysis, and (rarely) small amounts of other alloys as necessary to bring within specification. The low iron oxide in the slag (0.5%) indicates that the metal underneath is well deoxidized, and final silicon can be added without danger of forming silicate inclusions. Heat meanwhile has been brought to tapping temperature (eye control, and by fluidity and color of test); conditions are constant enough to establish a set time from slag-off to tap of 75 min. At any rate the idea is to get the metal out of the furnace as soon as equilibrium is established. Aluminum for grain size control is a ladle addition. Teeming temperatures should be high enough so no skull remains in the ladle.

Theodore H. D. Burke of Otis Elevator Co. remarked that basic steel castings were generally cleaner than basic electric ingots, which might be caused by one of several factors: Small furnaces have a higher proportionate slag volume, larger slag-metal interface, and a shallower bath — all of which make for more effective slag-metal reactions. Likewise the foundryman must make a comparatively fluid steel in order to cast his intricate shapes; castability and fluidity usually also make for clean steel.

Single Slag Practice

While the above has had principally to do with basic electric steel for ingots made by the usual two-slag practice, there are two methods now being practiced which use a single slag. As described by Wm. Farnsworth of Republic Steel Corp., one of these methods merely apes openhearth practice; fast heats result in as good steel as openhearth steel.

The other is not so simply explained, but consists in making a reducing slag, after melt down, to recover the alloys in the scrap. Little if any ore is contained in the original charge, the rust on the scrap being depended upon to oxidize the silicon. Lime is added to neutralize the silica made during melt down. Coke and ferrosilicon are then added to the slag to give it a reducing action and throw oxidized alloys (and phosphorus) back into the metal. When action is completed and tests returned, the bath is skimmed of most of the slag, the metal shaped up and deoxidized by manganese, silicon or otherwise, and tapped. This does not make a clean steel nor reduce any phosphorus, but it can be used with segregated scrap.

Critical Points

By Myron Weiss*
Guest Editor

THE EDITOR of *Metal Progress* asked me to be guest editor of "Critical Points" for this issue which closely follows the annual meeting of the American Society for Metals and the associated National Metal Congress.

The invitation gives me deep pleasure. For it lets me salute in this department the men who have made the ASM and *Metal Progress* the institutions they are. These men would not speak for themselves. I who know them long want to do so.*

To WILLIAM HUNT EISENMAN, ASM secretary and managing director of the National Metal Congress, the Society paid large tribute at the annual meeting in Chicago. His foresight, diligence and hard work has in 25 years built up the ASM until it is the third largest technical society in the world, in point of membership. It has 62 local chapters in the United States and Canada. It has a magnificent home in Cleveland. And it has $600,000 in assets. To celebrate Bill's 25 years of service, the ASM past presidents at the Congress gave Mrs. Eisenman and him a silver coffee service. Then, having looked at the interest money which the Society's $600,000 was earning, and weighing the lack of a pension fund for ASM employees, the National Trustees used the interest to buy Bill Eisenman a proper annuity. But, not yet satisfied with the honors they wanted to bestow, he was also elected a Founder-Member.

Thus the Society now has three living Founder-Members: Col. ALBERT E. WHITE, co-ordinator and 1921 (first) ASM president; WILLIAM P. WOODSIDE, organizer in 1913 of the Steel Treaters' Club, the ASM's embryo; and WILLIAM HUNT EISENMAN.

The following paragraph I ask to have printed as written:

ERNEST E. THUM was an engineer in ferrous and non-ferrous industries. He was a teacher. In September 1930, at its founding, he became editor of *Metal Progress*. He wrote for the men in our metal working industries. He got them to contribute to this publication. He, his contributors and his readers are the experts who fit science to industry. They are metal engineers. They produce finer metals with fewer alloys. They improve foundry practice and melting operations, welding and forging methods, machining procedures, heat treating practices, cleaning, finishing and testing. In their plants they may be entitled metallurgical or chief engineers. They may be top executives, plant managers or foremen. Whatever their titles, they are the men who know metals. And Editor Thum has 17,639 of them subscribing to this magazine which he edits . . . . And I, from varied experiences with all manner of publications, and despite a brief tour of duty as adviser editor of *Metal Progress* — I say that this is the best edited, most attractive and most widely circulated magazine of its kind† . . . . Advertisers in *Metal Progress* no longer are taking full advantage of the eye-appeal allowed by the page size and paper of this publication. Until the war forced a cut in page size, most of the ads *did* catch the readers' eyes effectively. Advertisers might well reflect that a smaller (or a larger) page affects the eye and mind differently.

If I go on like this I will not have all the space I want for "Critical Points". Yet I do want to give the salutes they deserve to RAY T. BAYLESS, assistant secretary, ASM, editor of *Transactions*, who breakfasted, lunched and dined every day of the Congress with the chairmen and speakers of the day's meetings to help plan their schedules; to MARJORIE R. HYSLOP, his assistant in these matters (and also managing editor of

*REAL EDITOR'S NOTE: Mr. Weiss was editorial adviser to *Metal Progress* at a critical period in its history. He was for many years a senior editor of *Time* magazine, and is now editorial counsellor for the publications of industrial concerns.

†Strong words!

The Review), to EVELYN GARDNER, Bill Eisenman's right hand in everything he does; and to the business staff — ED DONNELLAN, CARL OHLSON, CHESTER WELLS, and PETER FORD.

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NOW as to the National Metal Congress:

The outstanding news event was the first appearance before this technical society of leading industrialists to expound purely industrial problems to metallurgists. Metal engineers, like other diligent workers, are apt to put all their hearts, souls and minds into their immediate work and to lose sight of their places in the sun. In fact, at the Congress it seemed that many a man was working too hard to perfect production in his own plant, that he was working for the sake of production and not for the sake of winning the war, the main reason for production.

These speeches were off the record, another good reason for ASMembers to attend the annual Congress. You can calibrate their significance from the speakers who were there. ZAY JEFFRIES, technical director of General Electric's lamp department and chairman of the board of the Carboloy Company; Col. ALBERT E. WHITE of the University of Michigan's department of engineering; Vice-Pres. SAFFORD K. COLBY of the Aluminum Co. of America; Sales Manager L. B. GRANT of Dow Chemical's magnesium division; Secretary ERNEST V. GENT of the American Zinc Institute; Secretary F. E. WORMSER of the Lead Industries Association; Pres. F. W. WILLARD of the Nassau Smelting & Refining Co.

Although untellable in detail, the gist of this important session was this: The present productive capacity of aluminum and magnesium in this country means that immediately after the war we will have a great excess over our peacetime needs, and therefore we must develop new uses and markets with all speed. . . . We will be able to use all the lead and zinc we can produce. . . . The war has established new factories and relocated multitudes of people. Many will stay put. This may mean the loss of industry in old locations, comparable to the 1920's drift of textiles from New England to the South. . . . A carefully organized plan for stockpiling of scarce and surplus materials was presented.

Quoted at Chicago was Secretary of Commerce JESSE JONES: "I have no fear that government will deal unfairly with industries, because I am convinced that our people want to maintain the principle of free enterprise which is the foundation upon which our economy has been built." . . . This assurance seemed needed. The Federal Government has spent $15 billion in the erection of new plants. It owns about 75% of all our new plants. In fact, of the $70 billion invested in *all* U. S. manufacturing enterprises the Government owns one-fifth! These include 534 plants for the manufacture of airplanes, airplane engines and parts; 84 for the production and fabrication of aluminum; 116 for the production of machine tools; 40 for the production and fabrication of magnesium; 60 for the mining and production of minerals and metal products and 164 for the production of iron, steel and related products.

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TO PLAN for the future there is this phenomenon to go by: After the War of 1812-15, there was business hesitancy from February 1815 through the 1815 spring; a replacement boom from the 1815 spring through 1816; expansion in 1817 and through the 1819 spring; depression from the 1819 spring through the 1821 spring; recovery and prosperity from the 1821 spring through the 1825 summer.

After the War between the States there was hesitancy from April 1865 through August 1865; the replacement boom September 1865 through December 1866; simultaneously expansion of industry and railways from January 1867 through December 1868 and a trade recession with financial difficulties; recovery and prosperity from January 1869 through September 1873.

After World War I, hesitancy began with the Armistice of November 1918 and lasted into March 1919; replacement boom began April 1919, ended May 1920; finance and trade collapsed June 1920; recovery and prosperity ran from late 1921 to October 1929.

There is a notable similarity here in periods and their length, and it is more than possible that one can expect much the same after World War II, which began fuzzily and will end no man knows when. History shows that there will probably be a very brief period of business hesitancy. But how long will the replacement boom last? One year, two years, three years? When will come the expansion? the collapse? its severity? the eventual recovery and prosperity?

Dismantling of the German armament industry after World War I forced Germans to scrap obsolescent equipment and to tool up anew. Destruction of the Teutonic lair may again enable western Europe to retool anew. This would obsolete much of our American equipment. Shall we sell this equipment second hand? Shall we dump it? Who will buy, lend-lease or cadge it? South Americans? Russians? Chinese? And if we do not dump or scrap, what will our toolmakers and their like do?

Helmets and Flexible Body Armor ("Bullet Proof Vests" to Civilians) Are Now Worn by American Bomber Crews. Full vest (armored front and back) and apron, weighing 22½ lb., protects bombardiers, navigators, radiomen, and gunners. Pilots, as above, wear half-vests, armored only in front, since the seat pan and plane's armorplate protect them from the rear. Rip cord is looped in front and frees the airman and his parachute instantly . . . . Below is the vest which saved Lieut. Jack Fisher's life from a 20-mm. shell which exploded about 24 in. from his chest . . . . The armor, developed by the British, is true lend-lease in reverse. It will stop a .45-caliber army pistol bullet at 30 ft. (Photo by U. S. Army Air Forces)

THE INCREDIBLE RUSSIANS, you heard at the Congress, are melting non-ferrous scrap right in the battle field in portable furnaces heated by wood. . . . U. S. Ordnance troops are repairing guns, tanks and other equipment under fire at the battle front, Brig. Gen. HERMAN F. SAFFORD told a large group who saluted him with a special luncheon. The ordnance field men sometimes must counter-attack the enemy, said he. They give good account for themselves. Our ordnance is superior to that of the enemy. Our flyers are getting bullet-proof vests. Consequently the morale of our troops is high. . . . The United States mint will no longer make the new, confusing white pennies; it will revert to copper, using scrap shells.

An inexplicable oddity of the National Metal Congress was the rarity of military personnel. Production for warfare dominated the technical and scientific sessions as well as three whole hotel floors of industrial displays. A few ordnance men spoke. Also the brilliant MARY NORTON of Watertown Arsenal. Yet in the audience scarcely a uniform! You would think that men who are about to use munitions on the battle fields and oceans and in the air would want to know the science and the techniques of their manufacturers. You would think that logistics would back into the factory and the conference lecture room. But few men and women in uniform appeared.

ONCE upon a time there was an obscure American businessman who minded his own business, kept his mouth shut and sold honest-to-goodness supplies to railroads for honest-to-goodness dollars. When this businessman, WALTER P. MURPHY, died a few years ago he flabbergasted every philanthropic and institutional tout in the country. For, unknown to them, he owned $33,000,000, and without solicitation gave most of it to Northwestern University for a Technological Institute. The university moved an astronomical observatory

to make room for a modernistic grey and beige building to house the actual factory, machinery and gadgets that Mr. Murphy wanted the students to work with. Visitors to this Technological Institute during Congress week were persuaded that here was the most efficient plant in the country for teaching young men how to use both their hands and their minds at the same time. Phenomenal in an educational institution were the corridor showcases of U. S. manufacturers displaying their products. . . . Phenomenal too was the scene on the lawn of the Garrett Biblical Institute, a Methodist rock of decorous mores: Girls in shorts playing soccer, their bare legs flickering in the autumn sunlight.

THREE TRAINS of Pullman cars brought Canadian metal engineers to the Congress, a lively, inquisitive, enterprising group. The Alcan Highway, they expect, will open up the Far West of Canada, and its North West. Edmonton, where the highway begins, is a boom town. Canadian industry, still concentrated in the East from Windsor to Montreal, has expanded tremendously . . . . Note for the cleaning departments: Soap, scant in the U. S., is plentiful in Canada!

WAR CONFERENCE DISPLAYS were jammed from noon to 10:30 p.m. each day. You would think that in this war-sellers' market no one would bother with the market place which the National Metal Congress provides. Nevertheless, more than 200 concerns sent men and displays to promote their products for now and for after the war.

X-ray promises to become a commonplace industrial tool for fluoroscopy, radiograph and diffraction. General Electric has a mobile 1,000,000-volt machine for the examination of huge structures. Westinghouse has one that can make an X-ray picture in 1,000,000th of a sec. Mass-produced parts, carried by conveyor under a tube, may be radiographed automatically, with the aid of photo cells. Electronics for machine and temperature controls, for high frequency heating, for sorting — all are newly and well established.

Spraying atomized metal upon metal parts attracted much attention. This "metallizing" builds up worn machine parts, reclaims mismachined castings, surfaces equipment against corrosion. . . . Waxes to inhibit corrosion and to provide dry lubrication are the war contribution of S. C. Johnson & Son of Racine, Wisc. They ordinarily make floor and furniture wax. . . . HAROLD P. RANSBURG of Indianapolis came with a method of spraying paint on an object suspended in an electrical field. Particles of the spray become electrified, fly to the object and adhere evenly. . . . The Pangborn Corp. of Hagerstown, Md., makes blast cleaning equipment. Research led them to investigate what happened to blast cleaned metal surfaces. They found they were in effect peening the surfaces, that each particle in the blast was a tiny peening hammer, and that this surface peening induced compressive stresses in the surfaces and increased their fatigue strength. This is an ancient accomplishment (for example, Damascene steel swords) and a brand-new adaptation.

THE FOG lifted from the mouth of Delaware Bay one morning last winter, and a Coast Guard cutter darted toward a Portuguese freighter, bound from Lisbon to Philadelphia and laden with European refugees, which had anchored off Cape May over night. The cutter nosed against the freighter. A chunky Navy intelligence officer caught our Jacobs ladder. You saw only the top of his hat and shoulders as he climbed. Aboard, you could see that he was young and eager, and serious. Fog settled on us again. It stayed for the two days it took us to inch up the bay. In that dank time, I, the supercargo, got to know and like STUART STEFFEY, son of President Steffey of Firestone of Canada, grandson of the late George M. Verity of American Rolling Mills. Ensign Steffey, 24, already married, told me: "My grandfather's generation made their America. My father's generation is making their United States and Canada. My generation's time is now. I am hitting for all I can right now, and I will as long as I live."

The memory of this boat-rail philosophizing returned when the American Rolling Mills' business evangelist, BENNETT CHAPPLE, appeared at the Congress crying, "We must take our share in our democracy!"

IDEALS to remember, from the dinner:

President ROY ARTHUR HUNT of the Aluminum Co. of America, upon receiving the ⊜'s first Medal for the Advancement of Research: "Our aluminum research has always had these four purposes — to make aluminum cheaper, stronger, more useful, and more economical for use."

Dr. ZAY JEFFRIES; upon getting the first Gold Medal of the ⊜: "I want to pay tribute to the men who worked with me in developing the accomplishments for which I get credit." ⊜

Matters Relating to Heat Treatment

Reported by H. J. Elmendorf

THE field of heat treating, long a popular subject at ⊕ meetings, was well represented by diversified technical papers and group discussions. The newer aspects resulting from the field of research were covered in the morning technical sessions while the practical "know how" was brought out in the afternoon and evening group discussions by experienced production men from the scene of action.

Quenching, probably the most important single operation in the heat treating of steel, was discussed in one technical session from the standpoint of quenching power in a paper by **Spring, Lansdale** and **Alexander.** They brought out that there are very slight differences between new and used quenching oils in respect to their quenching rates. Likewise, the temperature of the quenching oil may be varied so as to obtain differences in the rates of cooling, and this may be used to compensate for the variations in cooling rate between light and heavy oils. It was further stated that primarily all quenching oils produce the same metallurgical effect, and accordingly the selection might well be based on a consideration of the operating temperatures so that a suitable oil is chosen from the standpoint of safety from fire and satisfactory cost. Discussion brought out that the newer quenching oils designed for high rates of cooling have been very successful in supplying improved hardenability to the leaner alloy steel compositions now in use.

Post and **Fenstermacher** on "Rates of Cooling in Blocks and Cylinders", and **Hollomon** and **Zener** on "Quenching and Hardenability of Hollow Cylinders" offered new methods of calculating cooling rates for particular applications. Calculated and experimental data have indicated satisfactory comparisons in both cases, and Hollomon and Zener conclude that hollow cylinders are more effectively quenched from the *inside* than can be achieved in the usual practice of outside quenching. Post and Fenstermacher offered a method of computing the rates of cooling throughout sections such as cylinders, bars and blocks. Their method is based on the assumption that heat flow during quenching is normal to the surface at all points and proportional to the difference in temperature between the surface and the coolant.

A broad view of modern quenching practice was presented at one of the round-table discussions; a brief account is given at the end of this review.

Sessions on the transformation of austenite came in for their full share of discussion and the remarkably large attendance proved the interest in the subject. Particular attention was directed to the austenite-to-martensite transformations; specific effects of alloying elements on the martensite transformation were also presented. **Payson** and **Savage** offered a simple formula to approximate the Ar″ point (or the "Ms point", as some have called it) in steel wherein factors for the various elements are employed. They also presented data to show that the Greninger-Troiano quench-temper method may be used to determine the depth of decarburization. Discussion brought out that the graph of carbon content versus the Ms point is not a straight line relationship throughout the entire range of carbon content; it deviates in the low and high carbon ranges, and accordingly some appropriate allowances should be made in the formula.

Chiswik and **Greninger** presented data on the individual effects of nickel, molybdenum, cobalt and silicon on the martensite transformation in steel and concluded that nickel decreased Ar″ in a 0.45% carbon steel uniformly at a rate of about 34° F. per 1% nickel. Molybdenum, up to 2%, neither raised nor lowered the Ar″ for 0.50%, 0.80% and 1.00% carbon steels; similarly silicon, up to 3.5%, did not influence the Ar″ point for 0.72 to 0.84% carbon steels. Cobalt, however, in the range of 3.4 to 7.6%, raised the Ar″ point for a 1.12% carbon steel uniformly at a rate of about 34° F. for each 1% cobalt. It is very interesting to note this behavior of cobalt as it agrees very well with what one might expect from the present known behavior of cobalt on the S-curve. It was likewise pointed out that the elements investigated did not alter in any respect the kinetics of the austenite-to-martensite transformations, as previously described by Greninger and Troiano.

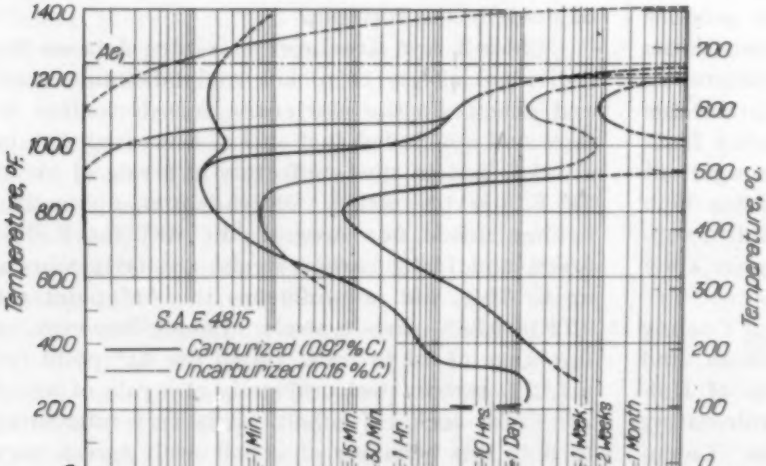
Elmendorf presented data to indicate that a controlled quench in the martensite transforma-

tion range would form a mixed microstructure of austenite and martensite which, upon subsequent immediate tempering, would produce a material preferable to the conventional quenched-and-tempered steel. These superior results are associated with a microstructure consisting of mixed bainite and tempered martensite, wherein the ductility is produced by the bainite and the high tensile strength by the tempered martensite. Discussion brought out that the mechanical properties reported are obtained from a tempered steel that consists of two structural components which vary both in hardness and ductility.

It is believed that future investigations in the field of ferrous heat treatment will be as much concerned with the martensite formation behavior as any other single item — a point also emphasized in the round-table meetings.

The effect of manganese on the Ar″, S-curve, and end-quench hardenability was discussed by **Russell** and **McGuire,** and their data substantiate the work of Greninger and Troiano on martensite determinations, and Bain and Davenport on the effect of manganese on the S-curve. The high manganese steels at temperatures below 900° F. showed as many as three different transformation structures at a single temperature.

Cruciger and **Vilella** presented isothermal transformation studies of S.A.E. 4815, both on the carburized case and the uncarburized core. It was very interesting to note the extreme effect of the high carbon in the case on the S-curve, as shown in the diagram below.



Isothermal Transformation Diagrams of S.A.E. 4815 (Light Lines) and of the Same Steel After Carburizing (Dark Lines). To prepare the samples for the latter curves some ⅝-in. square bars were carburized in compound for 18 hr. at 1700° F., the carburized surface 3/32 in. thick was parted, and these small samples austenized at 1800° F. for 20 min. Grain size was No. 7, A.S.T.M. (Cruciger and Vilella)

The present conception of tempering of steel might well have to be revised in the light of a series of papers presented by **Cohen** and associates in Massachusetts Institute of Technology. The problem was studied through a variety of precise measurements which led to some very interesting conclusions. Specifically: Hardened steel containing tetragonal martensite and retained austenite passes through three stages on tempering — *(a)* tetragonal martensite decomposes in the first stage to an aggregate of ferrite and a transition precipitate; *(b)* in the second stage the transformation of austenite into an acicular structure takes place, hardening being noted only when 20% austenite or more is present; *(c)* the transition precipitate formed during the first two stages decomposes into cementite particles which gradually coalesce into spheroids. Stress relief accompanies all three stages.

Researches into the heat treatment of bolts by **Sachs, Cole** and **Roth** indicated that the combination of bending and tension forces will require a bolt of lower hardness with a higher ductility in order to withstand the combined action than might be used when tension forces only are present.

Effects of prior structure and time and temperature upon the hardenability of several steels was reported by **Welchner, Rowland** and **Ubben.** Spheroidized and annealed steels form one general group, while hot rolled, normalized and quenched steels form another general group. The probable explanation of the respective effects on the hardenability may be based on the differing solubilities of the varying phases during the austenizing treatment.

Group Discussion

In the group discussion chairmanned by **H. W. McQuaid** and summarized by **H. J. French,** the subject of "Advanced Quenching Practice" was considered by panel members and discussed by an audience which filled the main ballroom of the Palmer House.

In the course of the afternoon's program it was brought out that quenching in oil comprises a three-stage operation, and it is necessary to extract heat at a high rate in the first two stages to obtain the most satisfactory results, while slow cooling through the third stage is helpful in equalizing stresses to minimize cracking and distortion. It was stated that increased cooling rates in oil

quenching might well be obtained by agitating the oil during quenching, and selecting the proper oil to meet the requirements.

Quenching in fixtures, principally to prevent distortion, is common commercial practice and it was emphasized that the fixture must be so designed that the oil is given a chance to perform its duty—that is, drive the oil vigorously in and around the piece being quenched. Primarily the fixture must be designed for the specific job with particular attention to the desired results. Many tricky ordnance problems are consistently being solved by the use of quenching fixtures.

Bright gas quenching for high alloy aircraft tubing parts is said to result in freedom from scale and decarburization. Carefully designed equipment is indicated, and particular attention must be paid to the proper gas analyses. "Bright gas quenching" may be compared to a fast air cool carried out in a protective atmosphere.

The austempering method of heat treatment consists of austenizing followed by quenching into a constant temperature bath maintained between 450 and 900° F., and holding for a required time until transformation is complete. This method may very well have advantages in the heat treatment of carbon steels within certain size limitations. Alloy steel properties from plain carbon steels are claimed for this process, particular emphasis being laid on the combination of high ductility with high hardness and a freedom from quench cracks. Hot oil quenching (at 200 to 450° F.), followed by immediate tempering will likewise produce high ductility coupled with high hardness.

Time quenching, in contradistinction to austempering, consists of quenching a steel into a medium capable of extracting heat at a high rate, holding in the medium for a specified time, and then transferring the piece into a slower cooling medium wherein the steel is allowed to cool to room temperature. The initial rapid quench, generally into water or brine, produces deep hardening. The hot steel is removed from this quench when sufficient time has elapsed for it to cool to some temperature below the nose of the S-curve. The piece is then transferred to a slower cooling medium, generally oil or air, wherein the austenite-to-martensite transformation takes place at a slow rate, which is an insurance against quench cracking. This type of treatment is everyday shop practice for many applications and has been very successful.

Martempering, a recent development in the quenching of steel, may well offer a means of reducing quenching cracks and minimizing distortion. The method consists of quenching the steel into a medium capable of extracting heat at a high rate, then transferring the steel into a constant temperature bath maintained at a temperature just above the point where the retained austenite starts to transfer to martensite (called the Ms point) and holding the steel in this bath until the temperature has equalized throughout the piece, then remove the piece and allow it to cool (and transform) in air. The initial cooling retains a deep layer of austenite, and the constant temperature equalizing treatment insures that the final cooling will proceed at a uniformly slow rate throughout the piece thus minimizing the stresses produced in the austenite-to-martensite transformation. In some cases the first quench is by-passed and the steel is then quenched directly into the constant temperature bath; however, this treatment may well have the same size limitations as the austempering process. By the slow and uniform cooling through the martensite range it is possible to quench intricate shapes and sections without the many difficulties attending the more traditional methods.

In the summary it was emphasized that to obtain the maximum in mechanical properties in a tempered steel, it is of paramount importance to obtain a quenched structure wholly martensitic. This statement was further clarified to the extent that products of high temperature transformation (ferrite, pearlite or both) cannot be tolerated; however, the martensitic structure may contain some retained austenite. This desirable martensite-austenite structure may be obtained by a number of methods, but it *must* be obtained for satisfactory hardening.

Non-Ferrous Metals

Reported by Frederick N. Rhines

THIS YEAR, at the National Metal Congress, was more than ever before a non-ferrous year, and in particular it was a light metals year. The activities were opened on Saturday with a program on "Production of Magnesium" under the auspices of the American Institute of Mining and Metallurgical Engineers and concluded Friday afternoon with an American Society for Metals group meeting on "Magnesium and Magnesium Alloys". Moreover, the meetings were amazingly well attended from beginning to end. A majority

of new faces were to be seen at almost all non-ferrous sessions, giving evidence of a rapidly growing interest in the finer points of handling these materials — induced, no doubt, by war-time manufacturing requirements and innovations.

Notes on the Displays

In the opinion of this reporter, the Metals Show (officially known as "War Conference Display") was more satisfactory than it has been in many seasons. This was partly the result of its accessibility and partly because of the interesting nature of the new things exhibited. With the show right in the Palmer House it became possible to drop in between technical sessions of any of the participating societies, and with the exhibits in separate rooms the decibel level was low enough to permit the visitor to talk with the exhibitor! Particularly evident throughout the show was the streamlined "packaging" of all kinds of tools and instruments. Could it be that there is some connection between the growth of such sales appeal and the vast entrance of women into industry? Some of the tools have all of the smartness of the latest vacuum sweeper!

Among the newer developments in equipment were numerous precision measuring instruments for the shop, an undetermined number of makes of fluoroscopic X-ray and microfilm devices for batch and continuous inspection, and several newcomers in the field of induction heating. One electrical concern exhibited "action photograms" exposed in one millionth of a second; it was said that the power of the X-ray beam used for this work is such that penetration through a small rifle barrel is possible.

Developments in induction heating were hardly less impressive. By the use of very high frequency electricity, produced with vacuum tube equipment, it is now possible to heat the very surfaces or localized zones of delicate parts that could not heretofore be spot treated. It is claimed also that ultra high frequencies will melt such refractory metals as molybdenum.

The exhibits of peening equipment seemed to be crowded at all times. Although the process is by no means new, its potential benefits have been largely overlooked in the past among the non-ferrous industries and are only now arousing widespread interest.

One would guess that rather more products of the metals producers were on exhibit this year than last — among them a number of new alloys. Of these, perhaps the most sensational is the "hot off the griddle" indium-zinc combination employed for electro-galvanized coatings, and having a corrosion resistance superior to that of ordinary zinc coatings. A new lead alloy containing silver is being used to produce lead-coated steel of attractive quality. New alloys of aluminum were also shown. It was suggestive of the tenor of the times to find steel manufacturers exhibiting brass, and a brass manufacturer exhibiting aluminum and magnesium!

Mining Engineers' Program

As has been said, the non-ferrous technical program of the American Institute of Mining and Metallurgical Engineers began with an afternoon devoted to recent developments in the production of magnesium. The magnesium producing capacity of this country has been increased somewhere near a hundredfold in recent years. This has been brought about both by expanding the facilities for the pre-war electrolysis of chloride, and the installation of large plants operating three distinct new processes which were outlined at the meeting. **Donohoe** described the methods employed at the enormous Nevada plant of Basic Magnesium, Inc.; the Pidgeon (ferrosilicon) and Hansgirg (carbon reduction) processes were discussed respectively by **Sebastian** and **Dungan.** No secrets were revealed to the initiated, but the stories of the development and rapid installation of these processes provided a highly stimulating afternoon. In an effort to estimate where all this magnesium will be used, after the war, **Breyer** pointed out that even today the consumption of magnesium has not kept pace with its production. There are, of course, a number of reasons for this, but the most important appears to be psychological. The design engineer is always reluctant to trust new materials in critical applications and the manufacturer, foreseeing much loss of time in solving problems of fabrication, is understandably slow to extend his use of magnesium.

A sharp curtailment of publishable research activity which resulted in an unusually brief technical program of the Institute of Metals Division, was offset in part by an all-day symposium on "Practical Aspects of Diffusion", ably arranged by **E. A. Anderson. Mehl** opened the session with a "Preface to Diffusion" in which he brought up to date his 1936 survey. On the practical side he pointed out that relatively few technical problems involving diffusion can yet be attacked in a quantitative manner, because of the lack of adequate mathematical methods for expressing diffusion in a material of complex microstructure. Some hope of being able to overcome this handicap in the near future is offered by the newly developed electrical analogue now being used for solving

parallel problems in heat flow. There is immediate need for more measurements of diffusion rates and for the clarification of the doubtful part played in diffusion phenomena by grain boundaries and anisotropic metal crystals.

The important problem of degassing metals for use in vacuum tubes was discussed by **Norton** and **Marshall** who have measured and analyzed the gases released from tungsten, molybdenum, nickel and iron when heated in vacuum over a large temperature range. It was found that the de-gassed metals do not reabsorb gases rapidly in storage. The observations indicated the solubility of nitrogen in molybdenum, and it was found that Sieverts' Law applies.

Perhaps the most interesting paper of the symposium was the one on "Diffusion in Alclad 24S-T Sheet", presented by **Keller.** A very careful metallographic and electrochemical study was made of the progress of copper into the pure aluminum surface, and the limits were established to which diffusion can proceed without destroying the corrosion resistance of the sheet. This work was brought to a thoroughly practical conclusion by outlining the permissible conditions for the heat treatment of clad material. A somewhat similar study of the rate of diffusion of indium into bearing alloys was described by **Smith.** Here again the important consideration is the effect upon the corrosion rate of the contamination and dispersal of the indium layer.

A welcome contribution came from England in the form of a brief paper by Miss **Gayler** on the part played by diffusion in the microstructural changes accompanying casting, working and heat treatment. **Kramer** also described some curious structures in chromized steel and your correspondent added his bit in the form of a review of plant problems involving the diffusion of gases in metals.

On Tuesday morning four unsolicited papers were presented, completing the technical activities of the Institute of Metals Division. The first of these dealt with a precision determination of the constitution of the lead-antimony and lead-antimony-silver systems. In making these studies, **Blumenthal** found that previous large discrepancies in the location of the lead-antimony eutectic are to be associated with under-cooling, which he avoided by stirring the melt during thermal analysis. It is disquieting to reflect that if large errors can be found in the accepted phase diagrams of a system as simple as that of lead-antimony there must be much worse errors in the more complex ones.

The peak attendance of the day was reached during **Barrett's** presentation of "Metallography with the Electron Microscope" — in fact, even the standing room gave out. The paper was in the nature of a progress report on the development of suitable metallographic techniques and the interpretation of the pictures obtained. **Keller,** in a discussion sent in by **Geisler,** exhibited some excellent electron micrographs of aluminum alloys made by the oxide film process.

In a continuation of their interesting investigations on the properties of copper at slightly elevated temperatures, **Martin** and **Parker** found that the long time rupture strength of copper is increased by the presence of small quantities of soluble impurities whose influence may be counteracted by the presence of oxygen. Fast cooling after annealing was found to decrease the time to rupture, perhaps because of the generation of imperfections in the metal. Your correspondent also presented another paper in his series on the oxidation behavior of copper alloys.

Setting up a Sand-Cast Aluminum-Alloy Cylinder Head for X-Ray Examination. Photo by Johnston & Johnston for Aluminum Co. of America

No account of this year's activities of the A.I.M.E. could be complete without mention of the annual dinner. The Chicago entertainment committee out-did itself. To begin with, the cocktails were excellent and effective. Then there was a professional entertainer. As a consequence, the affair took on an air of hilarity which culminated in a somewhat fuzzy rendition of several Yale songs in honor of Dr. C. H. Mathewson, President of the Institute.

Program of the American Society for Metals

The only strictly non-ferrous session of the American Society of Metals devoted to technical papers considered the problem of precipitation hardening. **Harker** justified the inclusion of the copper-gold alloys in this class. It will be recalled by some that last year, when commenting on a paper by C. S. Smith on the hardening of β brass, Harker presented some stimulating thoughts on the subject. This time he took the floor to present his ideas in a more complete form, and supported them by experimental evidence. Briefly, he argues that the copper-gold disordered solid solution develops, with ordering, minute sites of tetragonality, oriented within a single grain in four directions so that the crystal becomes distorted on a micro scale and hardened. Current views of the mechanism of age hardening would predict that this mechanism could in fact cause hardening.

Harrington, in a parallel study of copper-base and aluminum-base age hardening alloys, gave further proof of the importance of quenching strains in establishing the course of subsequent hardening. He proposed that the accelerating effect of strain might be due in part to a lowering of the solubility of the precipitating materials. **Fink** objected to this on the ground that repeated cold working in the course of solid solubility determinations does not displace the solubility limit, once equilibrium has been established. The discussion degenerated into a good natured free-for-all at this point, whereupon the chair, in the person of **Kent Van Horn,** announced that it would be necessary to charge an admission fee if the show were to continue, so the audience left the protagonists to enjoy their argument in private!

Group Meetings, no less than eight in number, dealt, at least in part, with the non-ferrous metals. Although it was announced that the talks presented were not for publication some specific exceptions were made, and an impression of the general tenor of the meetings can be given without violating the restrictions. The group meetings were educational in character for the most part, revealing little that is new, but bringing together various aspects of the subject of present-day importance, and providing a basis for specific questions solicited from the audience. Attendance at these meetings set an all-time high.

Under the heading "Powder Metals" a repeat performance of the 1942 session was given with a new cast of experts. There appears to be agreement that powder metallurgy is currently being over-publicized, and that too many are entering the field without a clear understanding of the real uses of the product and limitations of the process.

Later the same afternoon the foundrymen met to discuss their problems. In the field of non-ferrous casting attention was drawn to the advantages of the continuous casting of ingots and shapes, a practice which is growing rapidly at the present time.

Much attention was directed to the question of the future of the non-ferrous metals after the specialized war-time requirements have been met. It is clear that the potential supplies of the light metals, aluminum and magnesium, will far exceed foreseeable peace-time consumption. For this reason it may be anticipated that these industries will face the most difficult transition period at the end of the war. (The heavy metals producers have been called upon for less expansion and therefore expect less dislocation of their operations.) A continued major use of aluminum in aircraft will assist in solving the problem for the aluminum industry, but, unless surprising developments intervene, the use of magnesium in this application will remain small in comparison with the quantity of metal available.

The problem of salvaging scrap created in the course of manufacture and on the battlefield is one of great current importance. Specific directions for the proper segregation and disposal of industrial scrap were given at the meeting devoted to the subject. A book of instructions has recently become available: "Salvage Manual for Industry", obtainable for 50¢ by writing to the Superintendent of Documents, Government Printing Office, Washington, D. C. Anyone having a salvage problem would do well to obtain this book.

Concluding the activities of the week, a group from the magnesium industry described current methods in the fabrication of magnesium. While the handling of magnesium is fundamentally little more difficult than the handling of any other metal there are important differences in detail. Adequate printed instructions are as yet not generally available and this short course in the working of magnesium, supplemented by a well-made talkie, was an especially appropriate feature.

More Convention Notes

Points of Theoretical Interest

Reported by Malcolm F. Hawkes

MANY loyal convention goers who feared that theoretical metallurgy had succumbed to the rigors of war were pleasantly surprised by the wealth of new material brought out last month at Chicago. Especially well rewarded was the metallurgist interested in hardening and tempering of steel or in plastic deformation of metals.

Typical of the stimulating sessions in the first of these fields was the "one man show" on tempering by **Cohen** and his associates in the laboratories of M.I.T. In the first of four well-integrated papers, the fundamental nature of the various changes taking place when martensite and retained austenite are heated was studied by X-ray, metallography, hardness, magnetism, dilatometry and specific volume. Careful analysis of the experiments leads the authors to conclude that hardened steel passes through no less than three structural changes on tempering. Tetragonal martensite decomposes during the first stage into an aggregate of ferrite and a transition precipitate. The second stage consists of austenite transforming into an acicular structure with the same state of aggregation as the tempered martensite. During the third stage, the transition precipitate formed during the first two stages decomposes into cementite particles, which gradually coalesce until the spheroidized structure is achieved.

In the second paper of this session, the scope of the experiments was extended to cover steels with a range of carbon contents. It was shown that carbon has little effect on the temperature ranges of the three stages and on rates of reaction within these stages, but that the property changes become intensified as carbon increases. The third paper extended the work to 4% nickel steels with various amounts of carbon and molybdenum. No change in the general picture was observed, although nickel increases the amount of retained austenite while molybdenum acts contrariwise.

The fourth paper was another in the series of excellent researches on the tempering of high speed steel which have been coming from Dr. Cohen's laboratory. Here it was shown that, as the quenching bath temperature is raised from room to 500° F., the amount of untransformed austenite which will remain (following the subsequent common tempering treatment of 2½ hr. at 1050° F.) increases from zero to 22%. Triple tempering is then required for a final structure containing no untempered martensite — the structure required for maximum transverse strength.

In another session of interest to those seeking the fundamentals of steel hardening were three papers on factors controlling the formation of martensite and bainite from austenite. **Payson** and **Savage**, also **Greninger** and **Chiswik**, evaluated the effects of various alloying elements on the temperatures at which the austenite-to-martensite reaction begins and is complete. Most elements lower these temperatures, some only to a slight degree, but cobalt, anomalous as usual, was found to raise them. Similar work on manganese alone was presented by **Baldwin** and **Howald** who went on to show the effect of manganese on the S-curve and on end-quench hardenability at various carbon contents. Payson and Savage worked out an empirical formula based on the additive effect of alloying elements in combination on the Ms point — or should we call it the Ar″ point? (A move to standardize the nomenclature is badly needed at this time.) **Elmendorf** showed that austempering times could be materially shortened by first quenching to a temperature just low enough to form a small amount of martensite. After completion of the austempering process at a higher temperature level, the resulting mixed microstructure of bainite plus tempered martensite, if in proper proportions, is claimed to give the advantages of tempered martensite's tensile strength and bainite's ductility. In another paper on martensite formation, **Ellis** showed that if the austenizing treatment is very rapid, as in induction heating, the solution and diffusion of carbon, even in a 0.60% carbon steel, may be so incomplete as to result in a very non-homogeneous martensite. This results in a pseudomorphic pattern resembling the original (for example, coarse pearlite) having, however, the normal hardness of martensite. He proposed that a study of other properties of such structures would bear fruit.

Although theoretical studies of the transformation of austenite at higher temperatures were less common this year, one long needed paper was presented. **Shapiro** and **Strauss** assembled the best and most modern data on the influence of 15 common alloying elements on the

amount of carbon necessary to form the iron-carbon eutectoid. After showing that additions of some elements continuously increase this amount while others continuously decrease it, the authors classify the elements into two principal classes. The first class, typified by titanium and zirconium, form special carbides, and the eutectoid reaction is replaced by a peritecto-eutectoid reaction. As a result, some carbon becomes unavailable for pearlite formation.

Hardenability

No National Metal Congress would be complete without adding to the growing literature on hardenability. This year, papers dealt principally with the effects of austenizing treatment and alloying elements. **Welchner, Rowland,** and **Ubben** reported on the effect of time and temperature of heating on the Jominy hardenability of several 0.40% carbon alloy steels and S.A.E. 4620, starting in each case with various initial structures. In agreement with theory on the effect of austenite homogeneity on rate of decomposition, they found that proceeding from fine initial structures — such as produced by quenching or normalizing — to coarse pearlite or spheroidite decreased the hardenability, especially if the austenizing treatment involved low temperature or short time. Remarkably short times were sometimes sufficient for maximum hardenability, however.

Those who, for theoretical reasons, wish to isolate the effect of prior structure may make corrections for the varying temperature of quench by consulting the paper presented by **Jackson** and **Christenson.** They showed that the quenching temperature used in the end-quench hardenability test is important, especially for steels of low hardenability. The preprint contains curves from which this effect may be calculated.

Kramer, Hafner, and **Toleman** used the Grossmann method of multiplying factors to report on the effects of 16 alloying elements on hardenability. Most of the commonly used elements increase it, while cobalt, columbium, titanium, and tellurium were reported to decrease it.

Cruciger and **Vilella** presented an interesting study on the subcritical transformation rates of one particular alloy carburizing steel in the form of an S-curve for both case and core. Speculation on the nature of "X-constituent", or low temperature acicular ferrite described by **Davenport** in 1939, was included and it is hoped this may inspire someone to make a thorough study of this unwelcome structure, common in NE steels.

Hardenability calculations in the manner of Grossmann were also extended to hollow cylinders by **Hollomon** and **Zener.** To calculate the diameter of a round steel bar which will have the same center hardness as the minimum hardness of a hollow cylinder quenched in the same medium, the authors found it expedient to use equality of cooling rates, rather than Grossmann's equality of half-temperature times, as the criterion for equal hardness. **Post** and **Fenstermacher** showed that end effects did not alter center hardness on short bars until the latter become almost as short as they are broad. Methods were given for calculating cooling rates in sections of finite length, some of these calculations being combined with Jominy cooling rate vs. hardness data to predict hardenability in the sections.

Hardenability, however, is only one of the two factors controlling depth of hardening. The other is cooling rate, so it was with pleasure that we saw the recently neglected matter of cooling power of quenching oils reopened by **Spring, Lansdale,** and **Alexander.** These authors obtained cooling rate curves for eight different oils, some new and some which had been used and at various temperatures. Their observation that physical properties of the oil are far less important factors than temperature of the oil is important, but several discussors objected to going quite so far as to say that *any* reasonable oil is as good as the best if its optimum temperature is used. The difficulty of inferring effect on hardenability from cooling curves of various shapes was emphasized in the discussion; it was proposed that oils be judged on the basis of hardenability tests.

An interesting cooling medium used for heat treating aircraft tubing was discussed in a later paper by **Lehrer.** It consists of partially burned fuel gas of non-scaling composition blasted through jets upon the tubes as they pass through a cooling zone at the end of a continuous normalizing furnace.

Carburizing and Nitriding

These subjects were represented by only two papers this year, but much food for thought can be obtained from them. In the one, **Fong** and **Ragatz** reopened the argument on the mechanism whereby carbonate energizes the carbon in pack carburizing. Their results led them to believe that these carbonates do not decompose in a progressive and continuous fashion, but that decomposition ceases shortly after the carburizing temperature is reached. A mechanism was then proposed to explain why the charcoal nevertheless continues to be energized.

In the other paper, **Floe** presented data on the effect of degree of dissociation of ammonia on

the case depth in nitriding. Results showed that the white layer (largely Fe_2N) decreases in depth with increasing dissociation, although penetration below this layer is constant in all steels when heated in gas that is dissociated over a considerable range — from 15 to 65%. High dissociations save considerable ammonia, and their inferior penetration can be overcome by preliminary nitriding at 30% dissociation.

Properties of Alloy Steels

Several interesting papers on properties of ferrous alloys were presented. **Comstock** showed that increasing the normalizing or quenching temperature increases the strength of titanium steels because of increased solution of carbides in austenite, but that ductility is impaired because the grains are coarsened. Practical application of these facts leads the steel maker to roll at high temperatures and keep the grain size fine by the mechanical work. In low carbon steels, titanium, by forming stable carbides, may increase the amount of ferrite for a given heat treatment yet also increase strength. Whether this is caused by solid solution hardening in ferrite or by aging (precipitation) had not been determined.

Miller, Benz, and **Day** presented a wealth of data in their paper on creep strength, stability of microstructure, and oxidation resistance of chromium-molybdenum and austenitic stainless steels. Likewise, **Harder** and **Gow** made a thorough study of nearly 100 compositions to develop a heat resistant alloy low in critical metals for service up to 1400° F. (750° C.); they suggest 0.30 to 0.35% carbon, 2% silicon, 10 to 12% chromium, 4 to 10% nickel, and 2 to 12% manganese.

Burgess and **Bishop** showed that the optimum range of silicon content for resistance to growth and general deterioration at 1475° F. (800° C.) lies between 3.5 and 4.5% in plain gray iron and 0.5% lower in 2% chromium-iron. The latter maintains its as-cast strength even though this much silicon reduces its hardness and increases machinability.

In attacking the problem of control of graphite nodule distribution in malleable iron, **Simmons** has made an ingenious quantitative study of the effect of previous cooling rate. The fineness of distribution of nuclei increases markedly as cooling rates become fast enough to form a previous structure with martensite instead of pearlite as the matrix.

Theoretical metallurgists working toward a complete understanding of deformation and fracture in metals must have enjoyed these sessions immensely for their concise reviews of previous theories and experimentation. A fine example of this happy combination was the paper on plastic flow and rupture of metals by **Zener** and **Hollomon.** They first clearly summarized the two most prominent systems (those of Mohr and of von Mises) for specifying *(a)* the conditions for plastic flow, and *(b)* the nature of that flow and the strain hardening accompanying it under a given stress system. Following this, several proposals and observations bound to stimulate new interest in particular phases of the field were presented. The concept of resistance of individual grains to plastic deformation in relation to resistance of grains to relative movement (the latter subject to considerable change by grain boundary precipitates) was expanded to account for the differences in yield point phenomena between various metals. A useful tool in the study of the effect of strain rate and temperature on yield and fracture strengths was introduced in the form of an "equivalent strain rate" parameter containing both rate and temperature terms. This parameter is related in simple fashion to yield and fracture strengths, and suggests that test results at low temperature may be used to predict behavior during plastic deformation at very high rates of strain. Finally, the concept of reorientation of microscopic cracks is enlarged to give a possible explanation for the differences in flow phenomena occurring in different testing methods (for example, tension vs. torsion).

Cohesive Strength

One good old-fashioned session where the theoreticians refused to be badgered by purely practical matters was the one on technical cohesive strength. The program began with a review by **McAdam** of the work he and his associates have done on the cohesion limit of metals fractured in the absence of plastic deformation. Calculations of this property as a function of the three principal stresses in a stress field were plotted and shown to be in agreement with experimental results on sharply notched specimens. Exception to McAdams' calculations was taken by **Bridgman** because they assumed an essentially constant axial stress across the section of a notched tension specimen. Extension of Bridgman's calculations (reported in a separate paper at the convention) on axial stress distribution in the necked down portion of a tensile specimen undergoing plastic deformation led to the conclusion that such stress varies over the section. **MacGregor,** in turn, objected to Bridgman's calculations on the basis that Bridgman's initial assumption of distribution of strain across the necked down portion was invalid. *(Cont. on page 974)*

Steel Manufacture

Reported by Frank G. Norris

OCTOBER 17, 1943, is a date of importance for at least two reasons. It was the first day of the week of the National Metal Congress in Chicago. It was the first day of operation of trains over the subway in Chicago.

While these two events may appear, at first sight, to be of an entirely different order of magnitude, attempt to visualize for a moment the amount of work and planning and development on the part of a large number of men over a long period of time that has been necessary for the Chicago subway. Then make another estimate and you will arrive at an astonishing figure for the number of man-years of intellectual and physical labor represented in the results that are boiled down to a few thousand words and reported in a few minutes by one man at the technical sessions of the Congress. Then multiply that by 300. A similar amount of work and planning is represented in an equal number of developments that are brought to the attention of the members through the medium of the show. (This year the show was different — how could it be the same without Big Steel? — but by careful planning effective presentation was possible within the limitations of space, power and materials.)

A third group important to the success of the National Metal Congress is easy to overlook because so much of their work is even more behind the scenes than that of the authors of technical papers and displayers of equipment. I refer, of course, to the arrangers. This group includes the officers of all of the cooperating societies and the chairmen of the various program committees. It is dangerous to attempt to give credit by name because of inadvertently offending one omitted. It is redundant to comment on the obvious. But in spite of the danger and the redundancy I feel compelled, this year in particular, to join the universal applause for the efforts of genial and hard-driving **Bill Eisenman**, without whom the National Metal Congress and War Conference Displays could not exist.

I shall attempt to report some of the highlights and sidelights of matters that are of interest to the group that has come to be known as the steel making fraternity:

At a meeting early in the week the remark was made, in reference to the magnaflux testing of plates, that "if you look for something you can usually find it". This is certainly true of a metal convention in Chicago. For example, several metallurgists, either voluntarily or urged by their wives, visited the Art Institute. For a while I thought I was going to be stumped to find anything of openhearth interest at the Art Institute. The closest that I could come was **Sam Epstein's** favorite Rembrandt, "Young Girl at an O.H. Door". It happens on closer inspection that she is not at an open-hearth door but at an open half-door. This wasn't so good [Editor's Note: — Not even as a pun!] so I kept on looking and came to the room containing 16 water colors by Thornton Oakley on the general subject "Art in War". Here at last the openhearth was conspicuous — by its absence. The picture entitled "Steel" shows a blast furnace and a bessemer. One thing that puzzles me is why so many artists insist on drawing a blast furnace with three-pass stoves, and ore bridges with only one support.

I stumbled onto another instance of a familiar abbreviation showing up with a different significance. Having started to work in a steel mill at the American Works of the American Sheet & Tin Plate Co., I thought I knew what A.S.T.P. means. Sergeant **James Smith** (he is not the same individual as John Doe by any means) tells me that these letters now mean Army Specialized Training Program . . . . .

At an ⊕ Chapter meeting in Pittsburgh last week a member of the distinguished group of Campbell Memorial Lecturers remarked that often the metallurgists and the engineers do not speak the same language. A voice somewhere behind me, and thus unidentified, said, "That is putting it mildly; at our plant they don't even speak." I recalled this incident during the address on "Fuels of the Future" by **Ralph Sherman** of Battelle Memorial Institute, given Monday evening at the Dinner Meeting of the Chicago Section, A.I.M.E. I shall not attempt to summarize, but will repeat two questions which certainly should stimulate cerebration, not only by metallurgists and engineers but indeed by everyone concerned with the production and use of steel and coal:

The first of these questions is, "Why is low sulphur coking coal used for any purpose other than making metallurgical coke?"

The second is perhaps a little more technical: "Why have checkers under an openhearth furnace?"

Let me digress for a moment to recall a meeting I once attended on the cause and control of blowholes. All of the younger men, including myself, had a lot of fancy ideas which we were somewhat reluctant to present in so august an assembly. The senior consultant of the company, who had traveled a long distance to attend the meeting, interrupted the first speaker who was outlining the problem. He said, "Before proceeding any further, may I ask one question?" Naturally this request was granted. He asked, "What is a blowhole?" The speaker started to point out the three types of blowholes in rimmed ingots. All of the younger men, including myself, pinched themselves in various degrees of unbelief and thought "Is it possible that this man has so buried himself in the problems of the laboratory that he does not know what a blowhole is?" The senior consultant, having thus focused the attention of the group on matters of definition, then pointed out that about all we know is what a blowhole *was*, but we do not know what is *is* except to say that it is a frozen bubble. . . I wonder if we know much more than that today.

Plans are in the air now for technical sessions just over the horizon on segregation, deoxidation and on cleanliness as a function of ladle, furnace, and pit practice; certainly the last word has not yet been said about blowholes.

By now, if you haven't forgotten the second question posed by Sherman, you will realize that the obvious answer is unsatisfactory, namely: "Anyone who ever owned a pair of blue glasses knows that an openhearth won't run without checkers." To clinch the wrong answer beyond any possible argument one might add, "The furnace not only needs checkers, it needs checkers that are not plugged up." It turns out that the only way to keep checkers from plugging up is not to have any checkers. The ghost of an openhearth fuel that was tried and abandoned about the time of the last war refuses to lie still. Powdered coal either alone or mixed with oil is one of the newest developments in openhearth fuel.

Tolerances and Specifications

The October issue of *Metal Progress* is required reading for all metallurgists but particularly for those who attend the National Metal Congress. I want to make one or two citations from this standard reference work:

Each master of any art finds adequate means of self-expression within the limitations set by the medium chosen. What satisfaction the make-up man must derive by the comments—expressed within the limitations of the means at hand—he has built into page 617 by placing together the two contributions on accuracy, one on "Precision of Pyrometers" and the other on "Weights of Tubing". As regards the latter, it is beyond my power of comprehension to understand how a fundamental datum known to four places (weight of steel equals 0.2833 lb. per cu.in.) can yield a formula with a constant expressed to six decimal places. This may give more information about the type of calculating machine used than about the weight of a carload of steel to 0.01 lb. Could the weight of steel tubing be estimated any closer if a ten-bank machine were used instead of an eight-bank machine? How does the 1% difference between the results of the "correct" formula and a former one being criticized compare with the actual variation in tubing all rolled to the same nominal diameter and wall thickness? My slide rule says that a variation of 0.002 in. on outside diameter would give a weight discrepancy of 1% on a ¼-in. thick tube.

This example illustrates how far it is possible to get from reality and still be within the limits of the truth. The fable about engine bearings, in "Critical Points", page 611, completes an excellent background for the ⊜ group meeting covering purchase of steels on performance rather than chemical specification. The whole matter of specification and testing was pretty well summed up in two cogent remarks by **Earle Smith**: "Specify what is sensible, use it skillfully, and prevent waste." (Specification limits of about the same width as a reasonable check between laboratories scarcely meet this first requirement, for they allow only for analytical variations on identical samples; some additional allowance for reasonable variation in material as exhibited in two different samples must also be included.) "I am a trouble man. The more they catch in the plant, the less I catch outside."

Another truism which was emphasized at some of the sessions is that there are several aspects to almost any problem. Another way of expressing this idea is that every question has two sides. So often we attempt to assign moral qualities to this situation by wanting to know which side is right. My understanding of hardenability tests is that it is a customer's test. He has a given use in mind (it is the part he makes) and wants to select (or reject) steel for that part. If the steel is rejected he has done a good job in preventing himself trouble by catching it early. The standard tests are devised for this purpose. The steel mill's problem is a little different. The

mill has to know as early as possible whether a heat of special steel will fit the requirements of the order it is intended for. Suppose it is a little deficient in hardenability. If this is known in time it can be diverted to another order, or can be rolled to a smaller size bar. To make these necessary, if infrequent, adjustments, the mill metallurgist depends on grain size and critical point determinations. The information is not as elite as that revealed by a study of the isothermal transformation products, but it serves a useful purpose and has not been displaced by the more recently developed methods.

There are also two uses for some types of magnetic and electrical testing. If everything else is constant these tests will determine case depth. If case depth is known (or can reasonably be assumed) to be constant, they will disclose other sources of irregularity.

I did not stay through this meeting on testing methods because I wanted to hear the discussion on "Laminations in Sheet" at a simultaneous session. The general tenor of the speaker's remarks was that he is against them. (MEMO: Tell **Rough** to put a padlock on that bin and not put any laminations in the ladle for a while.)

Refractories

Some meetings are attended because one is attracted by the subject that is announced, but there are others that are attended because one knows that the man who is speaking always has something of interest on whatever subject he chooses. I went to the A.I.M.E. meeting Monday morning to hear **Robert Sosman** and certainly was not disappointed. His topic was "Conditions to Be Met by Silica and Basic Refractories in the Steel Plant".

I think there is no question but that the concept of FeO has served a useful purpose. Still and all we must not forget what Sosman said early in his talk, that in the iron-oxygen binary equilibrium diagram there is no compound at the percentage of oxygen called for by the formula FeO. So a postulate may be formed that it is not necessary for a thing to exist in order for it to serve a useful purpose. Having thus disposed of the necessity of explaining what FeO *is* (in either the liquid or solid state) Sosman gave it first place on the list of causes of destruction of refractories:

1. Reaction with FeO
2. Reaction with slag
3. Failure under load
4. Melting
5. Spalling
6. Mechanical breakage

The search of the alchemists for the universal solvent is culminated by an understanding of the characteristics of FeO which dissolves even the noblest of metals, platinum and gold. The ancient dilemma of finding a container for the liquid which dissolves everything is the everyday problem of the maker and user of refractories!

The demonstration of flexible sandstone was spectacular. This property of elasticity of natural stone leads to the suggestion that the elasticity of fireclay brick may be related to the service life of a furnace or vessel lining.

Another paper at the same session by **Kramer** on "Selection of Clay Refractories" showed the destructive effect of carbon deposition at 900° F. The presence of nickel caused the deposition of 30 times its own weight of carbon under the conditions of the test. Deposited carbon is fluffy so this much makes a pretty big pile.

Steel Manufacture

The A.I.M.E. meeting devoted to "New Steel Plants" was primarily given over to statistics of the equipment rather than to the metallurgical aspects. The metallurgical description of Republic's important new electric steel plant at South Chicago was ably outlined in a brief extemporaneous comment by **Earle Smith** (another redundancy to use the word "able" in the same sentence with mention of Earle Smith) at the A.S.M. group meeting on "Steel Making Methods" on Tuesday evening. Briefly the plan is double headed: One purpose is to provide an outlet for the commoner high phosphorus ores which the industry will be under ever-increasing pressure to use. The other is the obvious recent increase of electric furnace capacity, at the behest of governmental agencies, entirely independent of availability or price of clean scrap. Over a period of time I imagine the first of these objects will outshadow the latter, at present in the spotlight. The South Chicago plant is designed metallurgically to handle as high as 0.90% P in the iron. Currently a phosphorus content of 0.30 to 0.35% is planned. Such hot metal from the blast furnace will be charged into one of three 250-ton tilting openhearths and dephosphorized, and then given either a single or a double slag finish in one of a battery of 70-ton electric furnaces. The practice is similar to that already used at the Canton (Ohio) plant. (Such an outline for each new plant seems to me of greater interest than the exact number of turns on each transformer — but perhaps I would feel differently if I were an electrical engineer.)

The self-sufficiency of the steel industry is so well known that it is often overlooked. The pack-

ing houses have placed in everyone's mind the fact that some use is made of everything but the squeal, yet steel plants now hold an equally creditable position in the national economy. Imagine building a slaughter house out of squeals! This world's largest alloy steel mill, at South Chicago, was built to a surprising extent out of slag. 465,000 cu.yd. of concrete (slag cement, and slag aggregate) used in the Republic plant — and all of the buildings have risen from marshy ground backfilled with several feet of crushed slag — all since the first of this year. . . . .

The expression "to sweeten the burden" is used in a figurative sense with no special intention of adding sugar. A "sugar-coated ingot" refers not to a means of covering up a bad taste, but to an interesting development in mold coating. The sugar used may roughly be described as solidified Karo. About a pound is blown into each mold when at a temperature to form a browned coating.

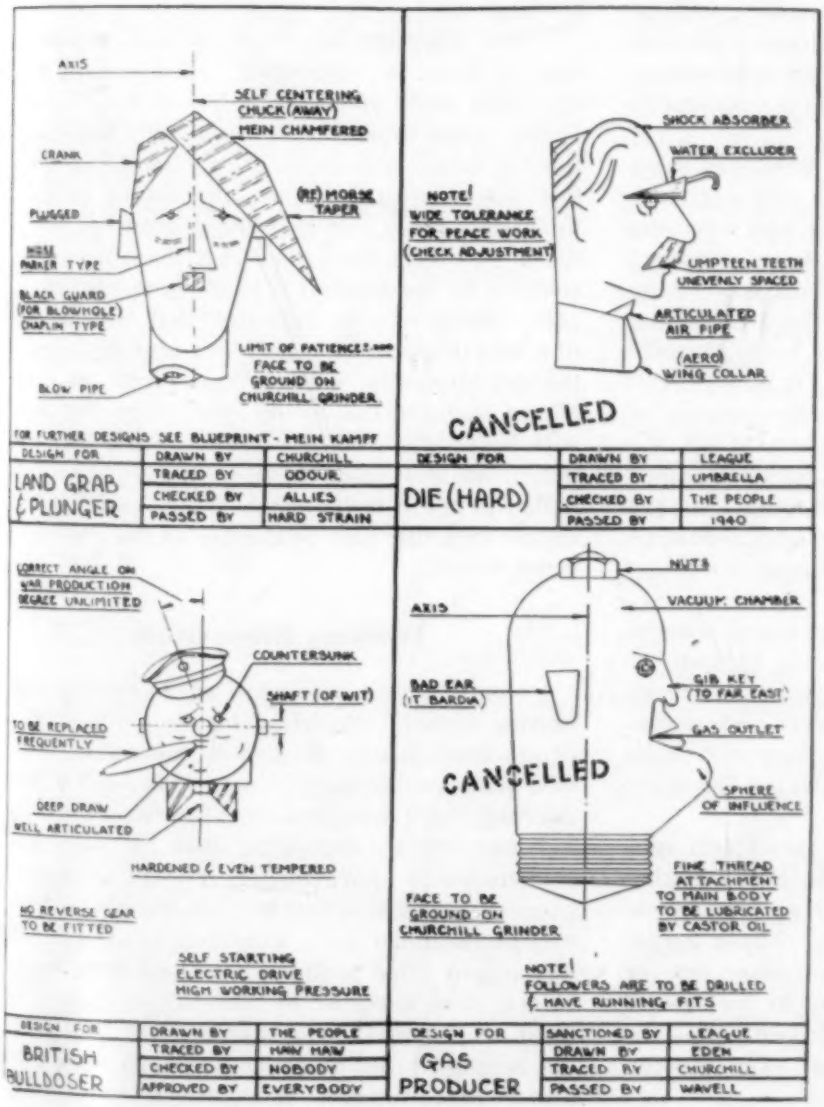
Miscellaneous Comment

A few weeks ago one of my colleagues told me he had a statistical question he would like to have answered. This was the matter of how best to present results so that they could be understood by an audience. About the best treatment of a series of rather involved data was given by **Sherman** in the talk mentioned near the beginning of this report. He used a series of colored charts which were beautifully executed. Considering the time and trouble of accumulating most data, a greater effort and expense would undoubtedly be justified in putting them in comprehensible form. . . . .

Another good job of condensing information into usable form was the "Combined Program" issued by Sterling Alloys, Inc. Most of the other programs were divided by societies. A handy pocket program to answer the question, "Where should I be right after lunch?" is appreciated. . . . .

Of course, no program can anticipate what papers will be of great interest and what ones will turn out to be rather dull. The number of individuals who linger after adjournment to participate in informal discussion is one criterion of the interest that has been aroused. From this standpoint the session on Quality Control Wednesday afternoon was certainly successful. The growing use of sampling inspection —or inspection by a standardized sampling procedure—was emphasized by several of the speakers. As was said somewhere else, "A very good way to put a new NE steel across is for the W.P.B. to say, 'You have to use it'." In a parallel sense, "A very good way to stimulate interest in sampling inspection is for the Navy to

These Shop Drawings Have Received Wide Publicity, But Are Too Clever to Resist. Authorship unknown —probably the result of a whole drafting room's ideas



start using the method." There are still some "100 percenters" who want to *know* what they ship (or accept), and find some comfort in the illusion of certainty which sometimes is dispelled by re-inspection. . . . .

In a certain sense that which is fundamental is not subject to change. The title of the ⊕ group discussion on "Fundamental Changes Reasonably to Be Expected in Metallurgy and Metals" is therefore a bit contradictory. Emerick's brief discussion of melting and refining of iron and steel considered chiefly changes likely to result from economic considerations. He was sure that the blast furnace will likely remain the most important means of reducing ore, and that the present trend to hot metal and duplex processes will continue. More and more steel will be finished in the electric (and electronic) furnace as the final step in either a cupola-bessemer-electric or a blast furnace-openhearth (preferably tilting)-electric combination. . . . .

One fundamental change that has taken place (and will likely continue) is in our attitude toward certain elements. The time was when the addition of a pinch of this or that was regarded as a hoax (and it probably was in a good many cases). Under the influence of the "substantial amount" theory, boron was found to be harmful and tellurium poisonous to steel. It now is realized that there is such a thing as an overdose of strong medicine. For me to comment on the current importance of intensifiers, which occupied the spotlight of two group discussions at the ⊕ and were mentioned in many others, would be to attempt to beautify a certain lovely flower by a futile tawdry effort. . . . .

Indium was the subject of one paper, a metal which is developing from a scientific curiosity—like magnesium a few decades ago or aluminum before that—into one of commercial importance. I wonder if this little stranger will some day be the subject of a symposium on "Methods of Analysis".

I have wandered a bit from openhearth subjects, but not as far as I thought I was getting when I stopped to see my idea of an ideal movie star (male) in the Firthite film. These people who make good cutting tools are looking out for the openhearth, because a shoulder at the base of the tool forms short, easily handled chips instead of long curly turnings. To some of our scrap suppliers: Please note!

Matters Relating to Metal Cutting

Reported by Nelson G. Meagley

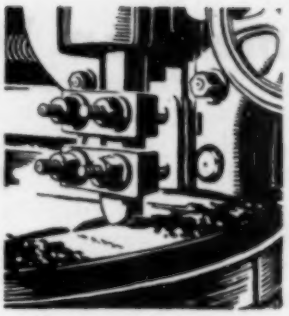
A CHANGE OF EMPHASIS between the Congress in '42 and '43 was reflected in the presentation of matters relating to metal cutting. In 1942, industry was in the great conversion to war production, and interest centered on making unfamiliar things from unfamiliar materials. A year's experience has been acquired and the behavior of NE steels, "Moly" high speed tools, and substitutes in general has been fairly well understood. Consequently interest this year turned more to the perfection of methods and a preliminary glance into the future after the war is won.

New materials are however still appearing. One of these is "intensified" steel, treated with extremely small additions of boron, with hardenability comparable to that attained by large additions of the more common alloys. Some experience has been acquired in the machining of these intensified steels and it is the general opinion of those who have used them that machinability in relation to hardenability is exceptionally favorable. Some reports indicated that the addition of boron in an existing steel will actually improve the machinability, entirely aside from its other effects, and that the use of lower alloy intensified with boron gives machinability much superior to that of the steel being replaced. Improved machinability is not at the expense of physicals, and this should certainly add to the use of these steels in peace times.

Working Magnesium

Magnesium has become an important engineering material since the start of the war and a Group Meeting was devoted to fabrication methods. Magnesium sheet is now available for deep drawing, but it must be heated somewhere between 450° and 700° F., depending upon the alloy, with a tolerance of approximately 150° F. for a given composition. The actual temperature should however be regulated quite accurately so as to control dimensions after cooling. Dies and punches are heated electrically or by gas. If small bending radii are required heat should again be used in the bending press or brake, although radii from 4 to 14 times the plate thickness, depending upon

the alloy, may be made in the cold. An additional advantage of heated sheet is the lack of spring-back in the stamping. A colloidal graphite in a volatile carrier is best sprayed on the work, and evaporation of the carrier leaves a film of lubricant for the drawing operations. It is very important that this graphite be thoroughly removed following fabrication. Dies and punches are made from almost any metal — steel, cast iron, magnesium, or aluminum.



The machining of magnesium was illustrated through a moving picture presented by the Dow Chemical Co. Several points of importance were brought out:

1. Keep tools sharp and cool.
2. Increase clearance in the tools for removing chips from cutting edges.
3. Lubricate with light oil and *never with water or soluble oil.*
4. Good housekeeping was stressed. Collect chips promptly and keep them in closed containers.

Magnesium is the easiest of all metals to machine and very high cutting speeds are used. The fire hazard must of course be watched, although with proper control it is not serious. The high machinability, together with the favorable weight-to-strength relationship, should result in greatly increased application of magnesium in post-war years.

Tools

Tools were given considerable space in the Group Meeting discussing "Salvage and Conservation". Tool conservation begins in the write-up and is based upon obtaining 100% usage of these critical materials. The following is a summary of the important points presented:

1. Select proper tool for the job.
2. Select the proper speeds and feeds for the material being machined.
3. Use correct geometry. Cutting angles are very important.
4. Use proper coolant. On some applications, too much extreme-pressure lubrication can be as bad as not enough, because the tool is prevented from satisfactorily contacting the work.
5. Surface treat the tools where this operation is practical.

More and more tools have been surface treated during the past year. The process consists generally of nitriding or chromium plating. Nitriding of high speed steel in partially cracked ammonia is not satisfactory, due to the resulting brittleness. Nitriding in potassium and sodium cyanide, it is said, considerably improves tool life on some applications. The bath should be closely controlled so as to maintain the proper concentrations.

Chromium plated tools have also increased the performance in some applications to an exceptional degree. A chromium plate is applied directly to the surface of the clean steel and is followed with a 500° F. toughening treatment to decrease the brittleness of the plate. The high hardness, low coefficient of friction, and anti-welding properties of chromium result in a superior surface for those cutting operations where these physical properties can be used to advantage. It is particularly advantageous in taps, drills, reamers, cutters and drawing dies, although its use has also been applied to turning tools, including the form tools. It is important of course not to neglect the proper backing to the plate, as hardness and toughness in the tool must be relied upon to resist crushing of the case.

Even after all the properties inherent in cutting tools are utilized by proper organization of the tool set-up, the conservation program is not completed. Grinding is extremely important and maximum efficiency is obtained by centralizing this operation in a separate department where the technique can be more readily supervised. (P.S. Save the grindings, for high speed swarf is a high grade tungsten ore.)

Again, after the customary life of a cutting tool has been reached, it is not ready for scrap. The piece can be used as a blank for smaller tools, or as a tip in a shank of less critical material, attached by modern brazing or welding methods. Broken tools such as cutters, drills and reamers, can be repaired by brazing and give a service life comparable to a new tool. Welding rods have been perfected for the building up of high speed surfaces so that bad chipping can often be replaced.

Caution must of course be practiced in any heating operation which results in the formation of austenite, as a draw is necessary to recondition the tool before rehardening if the full physicals in high speed steel are to be used.

Heat Treatment of Toolsteels

An excellent paper was given by Gordon and Cohen of the Massachusetts Institute of Technology on "The Effect of Quenching Bath Temperatures on the Tempering of High Speed Steel". It was shown by the authors that maximum physicals follow quenching to 80° F. and a double draw at 1050° F. If however, the steel is quenched

to 220° F. followed by the same double draw the martensite formed in the second draw is untempered, and the process results in a considerable increase of brittleness.

The injurious effect of placing tools in the draw before room temperature is reached can be compensated for by additional tempering operations. When the geometry of a piece requires caution in cooling to room temperature, the steel can be given a multiple draw to obtain practically 100% transformation of the austenite, and tempering of the resulting martensite. For example, three draws at 1050° F. are each followed by complete cooling to room temperature; the third draw tempers the martensite released on cooling from the second draw. Shock loading property of such a steel is comparable to that resulting from cooling to 80° F. and double drawing at 1050° F.

The use of the microhardness tester in the location of austenite on the surface of high speed steel was brought out in a paper by **Constance Brodie,** in which the technique for the use of this instrument was explained, although the details of this application in exploring for retained austenite was not elaborated upon.

Trends in Metal Cutting

One notable session of the Congress was devoted to changes reasonably to be expected in fabrication methods, wherein the speakers attempted to raise the curtain of the future to show where the trends now apparent will lead in a post-war period. It was felt that carbide materials would have an increased application, and their utility would be especially enhanced by a more widespread use of negative rakes in tools for turning, planing, shaping, and milling. Such tools will require new machines having greater power and speeds for utilizing the full capacities of the cutting elements. In a contrary direction it was felt that improved forging practice will greatly reduce the amount of machining necessary, and the precision casting of ferrous metals will still further accelerate this trend.

The trend in metal cutting is two-fold. First, toward increased refinement and precision throughout industry so as to utilize to the fullest extent the metal cutting knowledge now available; and second, toward a more scientific approach to the study of the behavior of metals in cutting operations.

Welding Highlights

Reported by J. V. Kielb

FROM the opening session of the American Welding Society's convention by President **Hansen** until the closing four days later, the proceedings certainly illustrated the tremendous strides that have taken place since 1942's national meeting in Cleveland. This progress and its value were indicated by the number of persons attending this convention during the present emergency, braving travel and hotel congestion. Discussions and interchange of ideas, and the bartering of welding facts, continued long afterwards in lobbies, hallways, and private rooms.

The Samuel Wylie Miller award was given to **Dr. D. S. Jacobus** for long and outstanding achievement in the welding industry. Other awards were made for meritorious papers about all phases of the welding industry. Technical sessions dealt with research and development, manufacturing welding for Navy and Army ordnance, and industrial plant problems. Cooperation between all branches of effort was the keynote; with it much can be accomplished in developing the science and art of welding. The present emergency is the greatest factor in producing these results, and Lt-Col. **Gillon's** address clearly indicated that the partnership between ordnance and industry resulted in greater production and superior equipment to that of our enemies. Performance in combat is the best illustration and test for our weapons. But to men of industry, this convention revealed that these developments in research and manufacturing must also be maintained during normal times.

Research and Development

It was clear that much research and development has been completed during the past year. Work described was conducted by Battelle Memorial Institute, Rensselaer Polytechnic Institute, Naval Research Laboratories, Watertown Arsenal, and Lehigh, Columbia, Ohio, and Illinois Universities. Furthermore, in the manufacturing laboratories of General Electric, Westinghouse, Aluminum Co. of America, Detroit Edison, Taylor-Winfield, and many others, development work in all phases of welding has been conducted. Thus,

we find that both the theoretical and the practical fields have been investigated. Some results have already been put into practice; work is being continued, some of which will be modified by the floor discussions at these sessions.

The above remark certainly applies to the studies described by **Comfort Adams,** the grand old man of welding, in his first presentation of the "Adams Lecture" at the outset of the convention. He spoke of the transient phenomena which occur in very rapid spot welding of sheet — that is, the generation and flow of electricity, the resulting heat, and the conduction of that heat during times as small as 0.001 sec. and shorter. To contrast the extreme conditions that might be related solely to the metal being welded, he showed curves approximating the magnitude of several of these transient phenomena, as they vary in time and space, for aluminum (a fusible metal of high conductivity for heat and electricity) and for 18-8 stainless steel (a metal of high melting point but of low conductivity). An inescapable conclusion of the preliminary studies, both theoretical and practical, was that better spot welds can be made in shorter times than those now being used. Shortening the time might confidently be expected to produce less distortion and internal stress in the work, to use the heat generated at greater efficiency and thus lead to smaller electrical machinery. However, the controls must be ever more precise. While the ideal has not yet been reached, Dr. Adams showed some test welds in aluminum sheet which, when sectioned and etched, possessed only an embryonic "nugget" of heat-affected metal, yet which had higher shear strength than asked for in current specifications.

Weldability

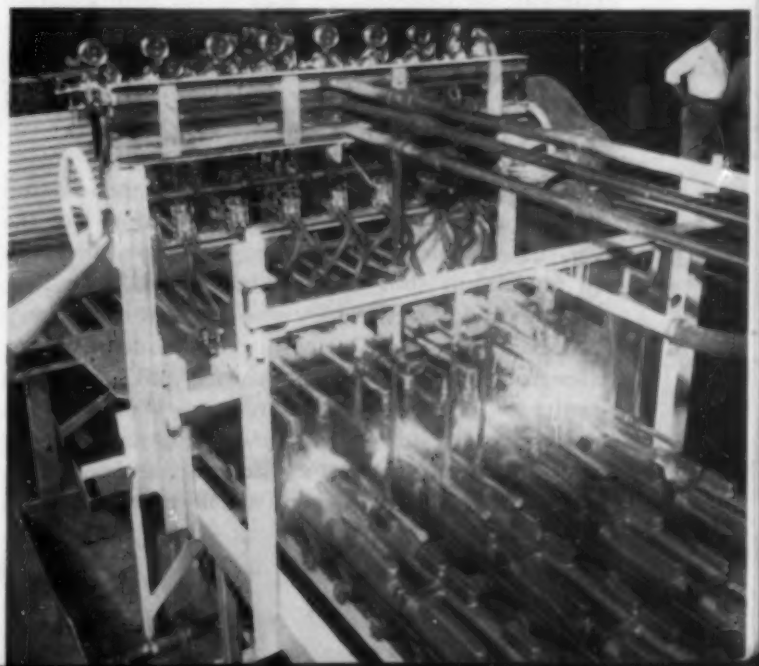
Research on "weldability" — that elusive property of metals — first established the cooling rates around the fusion areas on plain carbon and low alloy steels. Although work was done on ship steel corresponding to A.S.T.M. specification A131-39, it was found that analogous results would be obtained on S.A.E. 1035, N.A.X. 9115, and NE8620 steels, due to the fact that the thermal properties of these steels are similar. Tests were conducted on several plate thicknesses with temperatures ranging from 37 to 400° F., and cooling curves were recorded between temperatures of 1300 to 700° F. Factors that affected the cooling rates were as follows: Energy input in Joules per unit length of weld, plate thickness, plate temperature and joint geometry. The first mentioned factor takes into consideration the arc speed, voltage, and current.

It was clearly brought forth that the welding engineer, through the application of the S-curve, can predetermine the temperature range of transformation, the metallurgical structure obtainable in the adjacent zone to the weld, and finally, get some indication of any special welding procedure that may be necessary. In plain carbon and low alloy steels, the development of pearlitic-ferritic or martensitic structure is possible. Martensitic structure in the fusion areas is associated with compression strains arising from volume changes associated with transformation of austenite, but by developing a tempered martensitic structure, the residual strains are reversed and a tougher and more ductile structure will result. This can best be done by preheating these steels; temperatures can be estimated with the help of S-curves.

As to the cooling rate curves, these can be determined mathematically and heat-flow charts developed for the particular steel. These cooling curves emphasize the difference between the first pass and top pass layers of weld metal. The cooling rates for the first pass were lower than that of the top pass layers, and this causes the well-known variation in hardness of these layers.

Although these cooling curves covered the weld fusion area, it was revealed that further studies are being conducted on "first pass cracking". For years this has been one of the greatest difficulties existing in the welding industry, and by next year at this time, or before, it is hoped that this problem will be licked. Another welding problem is the peening of weld metal in butt and

Tank Tread Grousers (0.40% Carbon Steel) Hardened ¼ In. Deep to 500 Brinell in Four Conveyor Lines. Cleats are preheated with natural gas, heated to hardening temperature by multiflame oxy-acetylene torches (water cooled), then spray quenched. Capacity 120 per hr. Photo by Air Reduction Sales Co. at Trinler, Inc., Chattanooga, Tenn.



fillet joints which again was discussed in several sessions; it is to be hoped that studies by Prof. **Henry** of Brooklyn Polytechnic Institute will establish some definite data on this item.

Work by **Victor Paschkis** of Columbia University ties in directly with the work carried out at Rensselaer, and indirectly with that at Lehigh University. He has developed cooling curves by electrical analogy. In applying a "heat and maximum flow analyzer" to the top pass of 1½-in. plate, the charts checked very closely the actual cooling curves made at Rensselaer. As yet, the method probably cannot be used in practice because not enough reference curves are available; more correlation with direct thermal measurements is necessary.

Other talks on research developed during the past year revealed the hardness of weld beads on 34 War Department steels. In most cases there was a general and consistent relationship between maximum hardness and carbon equivalent; as was to be expected the alloy steels with nickel and chromium gave a higher hardness for a given carbon content than the plain steels. It was pointed out that steels which developed hardness in excess of 350 Vickers or showed cracks were ordinarily weldable with a preheat of 300° F., while steels which developed maximum hardness below 350 Vickers were weldable at —20° F. Hardness of weld beads decreased as the plate temperature was increased to 300° F. but in decreasing plate temperature from 65 to —20° F. a few steels slightly increased in maximum hardness while others softened a little.

Lieut. **Herres** of Watertown Arsenal described the above matters in his talk on the "Evaluation of Weldability of Alloy Steels". He summarized the general difficulties encountered thus:

1. Formation of bead metal cracks.
2. Development of unsuitable mechanical properties in the heat-affected zone of the base material.
3. Contamination of the weld material by elements from the base plate.
4. Development of high stresses during welding.

Welding in Manufacture

Vast progress as to methods and production was disclosed during this convention. In the resistance welding field, many of the difficulties in aluminum spot welding have been overcome. Maximum joint efficiency and strength have been achieved by proper cleaning methods, by new accessories to welding equipment, and by correct sequence of spots. Although most of the test pieces were tested in tension, a program is under way to obtain results in fatigue and impact.

A heavy press welder which provides seven different currents and time intervals was described although complete data on its performance are still to be accumulated. Studies have been completed on S.A.E.1020, 1065, and 4130, in plates ¼ to ¾-in. thick. The time cycle in this welder apparently affects the grain refinement and — of course — the tempering effects. Welds were evaluated by impact and shear tests, metallographic and hardness analyses; impact was considered most important for fixing proper technique.

Papers about the flash welding of nickel, and use of high nickel alloy rod in airplane construction, illustrated to all that much progress resulted from newly developed resistance welding equipment. Such progress has also increased production. Synchronously controlled timers, voltage compensators, sequence timers, weld recorders, and stored energy welders have all helped.

Persons attending the sessions on railroad welding and shipbuilding found many new items of interest. It is clear that marked progress had been made in the testing and training of welding operators, in welding equipment and supplies, welding procedure and techniques, allied processes, and in that coordination which leads to good control. Production planning, discussed by **W. B. Bowen**, can coordinate operations of fabrication and transportation from plants 350 miles from the assembly line. Welding jigs and positioners are essential and reduce the time required for sub-assemblies and pre-fabricated sections. Proper timing, and handling of operations of these sections, was essential in order to meet the assembly requirements.

H. W. Pierce presented a report from the Thermal-Stress Subcommittee of the Welding Society's Marine Committee, largely devoted to cracking in hull joints. This topic attracted many individuals interested in all phases of welding, for many of the points have direct application to the railroad industry, now and in the future. During this emergency, innumerable locomotives and other pieces of equipment have been repaired by welding, thus saving many of the units from being scrapped. All-welded locomotives and railway cars have been made, and it was expected that much experience gathered during this era will be extended to welding control and planning in the railroad industry.

In other sessions, talks were held on aircraft manufacturing, application of automatic flame cutting in industry and its development by electronic controls. Reclamation of tools — which is playing an important role during the shortage of high speed tools — was explained. Pressure vessels, piping, and welding and brazing of nonferrous materials were other topics discussed.

Induction Furnace for Electric Melting of Aluminum

By Manuel Tama
Vice-President, Ajax Engineering Corp., Trenton, N. J.

ALUMINUM is a product of electricity. It is the only one of our common metals which can solely be produced economically by electrochemical methods, with plants located in areas of cheap power. The aluminum industry is electrically minded throughout, and yet the melting and alloying of aluminum is performed in electric furnaces only to a small extent. It costs 10 kilowatt-hours to produce one pound of raw aluminum from the ores, and only one-fifth of a kilowatt-hour to melt one pound of aluminum or aluminum alloy. In view of this anomaly, the metallurgical and economic aspects of electric melting as applied to aluminum and its alloys will be discussed briefly in this article.

Power Requirements — Aluminum production in this country will be on the order of two billion pounds per year in 1943, according to recent estimates. This requires twenty billion kilowatt-hours of electricity; an amount which equals 12.5% of the total energy produced in the United States in 1941. Assuming that all the aluminum produced would have to be melted at least twice before fabrication, the amount of power required for such operation would be on the order of 800 million kilowatt-hours each year, which is equivalent to 4% of the power required to obtain maximum production of metallic aluminum. In other words, if the production of virgin aluminum were to be reduced by only 4%, enough power would be freed to melt electrically all the aluminum ingot and alloy made in this country for rolling and foundry purposes.

Heat Content — The energy required for melting metals, usually called the "heat content", consists of three parts, namely: (1) The heat required to raise the temperature of the solid metal to the melting point; (2) the latent heat necessary to change from the solid to the molten state at the melting temperature; (3) the heat needed to raise the molten metal to the desired pouring temperature. The total amount of heat thus required is usually plotted in charts, as shown on the next page, which give in solid lines the heat content of the principal metals (aluminum, copper, iron and zinc) in terms of kilowatt-hours per pound at different temperatures. It will be noted that aluminum needs much energy *per unit of weight* for melting, and is only surpassed by iron.

However, inasmuch as many of the physical characteristics of metals, such as tensile strength and electrical conductivity, are not judged by weight, it is also interesting to plot the heat content in terms of kilowatt-hours per cubic foot — in other words, in terms of energy per unit of volume. The same drawing shows the heat content of the same metals plotted in this manner in dotted lines, and it will be seen that aluminum has a *low* heat content per unit of volume as compared with the other metals.

Types of Furnaces — For electric melting of aluminum two types of furnaces have been developed and used, namely, external resistor furnaces and induction furnaces. The first operates on the principle of temperature pressure and the second on voltage pressure.

One striking difference between the two types of furnaces is that in the resistor furnace a high temperature (2000° F.) is produced *above* the metal bath, while in an induction furnace all the power is generated *within* the metal, only slight differences of temperature are found within the metal bath, and much lower temperatures prevail in the zones above the hearth (less than 1000° F.).

Operating Principles

Radiant Resistor Furnace — The working principle of the external resistor furnace is contained in the modified Stefan-Boltzmann equation,

$$W = 50.5 \cdot A \cdot \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \cdot F_s \cdot F_e \cdot 10^{-6} \qquad (1)$$

as quoted from McAdams' book on "Heat Transmission", in which W is the net rate of heat radiation in kilowatt-hours, A is the area of the radiating or receiving surface in square feet; F_s is a factor to allow for the average angle throughout which one surface "sees" the other; F_e is a factor to take care of the individual emissivities of the two surfaces, and T_1 and T_2 are the absolute temperatures (degrees Fahrenheit plus 460) of the radiating and receiving surfaces respectively.

The heat flow, according to equation 1, is limited by the temperature T_1 of the resistor elements, which cannot exceed 2000° F. without endangering the life of the best resistors available. Another limitation is given by the low emissivity factor of aluminum, which lies between 0.113 and 0.192 for solid oxidized aluminum and between 0.12 and 0.17 for molten aluminum. The amount of power which can be safely applied to a radiation furnace per unit of bath surface therefore lies between 3 and 4 kw. per sq.ft., and a furnace of this type consequently requires a shallow bath of considerable surface in order to melt at a commercial rate. The large surfaces and the high temperatures prevailing above the molten bath necessarily increase the heat losses and the oxidation rate. Radiation furnaces, therefore, cannot be expected to melt more than 4 lb. of aluminum per kw-hr.

This type of furnace has not been used to any extent in the United States.

Induction Furnaces — The fundamental law governing the induction furnace is usually called Joule's Law, wherein W is the power, or heat, in kilowatts generated by a current of I_2 amperes flowing through the molten metal secondary of a furnace having a resistance of R_2 ohms:

$$W = (I_2)^2 \cdot R_2 \cdot 10^{-3} \qquad (2)$$

In an induction furnace, the current I_2 is impressed into the secondary by electromagnetic induction, according to Faraday's Induction Law, without need of electrodes or other means which would impose a limitation on the amount of current which can be safely transmitted to the secondary circuit (consisting of part of the metal being heated). Heavy currents can therefore be safely utilized for obtaining high power rates in spite of the low resistivity of the secondary circuit. For example, in a furnace of 125-kw. capacity, the secondary circuit has a resistance of only 140×10^{-6} ohms, and a current of 30,000 amperes is necessary to obtain the full power required. Some limitations are imposed on the amount of power which can be safely applied to one melting circuit, due to overheating and slag action on the refractories, but much progress has been and will be made by persistent research work.

Another limitation of induction furnaces in the past has been due to the low power factor inherent, particularly, to furnaces of large capacity. The secondary circuit is a closed loop with one turn. It has, therefore, in addition to the resistance R_2 a reactance, expressed by $2\pi f \cdot L_2$, where f is the frequency of the alternating current and L_2 is the coefficient of self induction in Henrys.

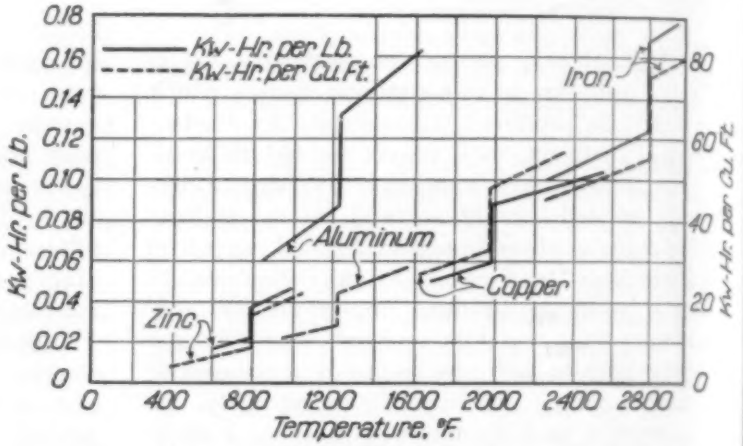


Fig. 1 — Heat Content of Zinc, Aluminum, Copper and Iron Expressed in Terms of Energy per Lb. and per Cu.Ft.

The power factor is given by the equation:

$$\cos\varphi = \frac{R_2}{\sqrt{R^2 + (2\pi f \cdot L_2)^2}} \qquad (3)$$

Equation (3) shows that one way to improve the power factor would be to lower the frequency f of the power supply and this method was extensively used in the early days of induction furnaces for melting steel. Today we have excellent static capacitors for improving the power factor of induction furnaces, using standard frequency in an efficient and economical way.

Joule's Law — equation (2) — can also be written as follows:

$$W = \frac{(E_2)^2}{R_2} \cdot 10^{-3} \qquad (4)$$

with the same denominations of equation (2), except for the term E_2 which represents the tension in volts applied to the secondary.

In an induction furnace the voltage of the

alternating current power supply is applied to the primary, consisting of a copper coil of n turns embracing a laminated iron core. If the supply voltage is called E_1, only a fraction of it, given by equation (5)

$$E_2 = \frac{E_1}{n} \cos\varphi \qquad (5)$$

is transmitted to the secondary, in phase with the current, to produce heat. By substituting equation (5) in equation (4) we find

$$W = \frac{(E_1)^2 \cos^2\varphi}{n^2 R_2} \cdot 10^{-3} \qquad (6)$$

This is the operating equation of an induction furnace which discloses the following characteristics:

1. The power absorbed by the furnace can be varied within wide ranges by changing the voltage applied to the primary.

2. The power varies with the square of the voltage.

3. During the entire melting period (wherein the power factor, number of turns of primary and resistance of secondary remain unchanged) the furnace will draw constant power. This is important because induction furnaces of this type will melt continuously with the power rating for which they have been constructed, without fluctuations, thus giving a steady load for the power supply.

4. Temperature does not appear at all in the operating equation. The induction furnace works on voltage pressure, and temperature is not the primary force. In an induction furnace it is possible to attain any temperature by applying the power long enough and the only limitation is given by the softening point of the refractories.

In contradistinction to resistor furnaces, the induction furnaces are provided with a deep bath of comparatively small cross section. The power rate per unit of bath surface is between 12 and 16 kw. per sq.ft. — that is, three times larger than in radiation furnaces, as explained above. Production rate is on the order of 5 lb. per kw-hr.

Construction

While induction furnaces have been used in the past very extensively (chiefly for melting copper alloys) it has taken a long time to develop a good and reliable furnace for melting aluminum alloys. The chief difficulty to overcome was caused by the low specific gravity of aluminum, which did not provide the slag particles contained in the bath with enough buoyancy to float them to the surface. Many attempts have been made to melt aluminum alloys in induction furnaces, but it was found that they could not operate continuously because the melting channels were clogged or contaminated with non-conductive particles which interrupted the secondary circuit. It is inherent to induction furnaces that the full cross section of the secondary should consist of

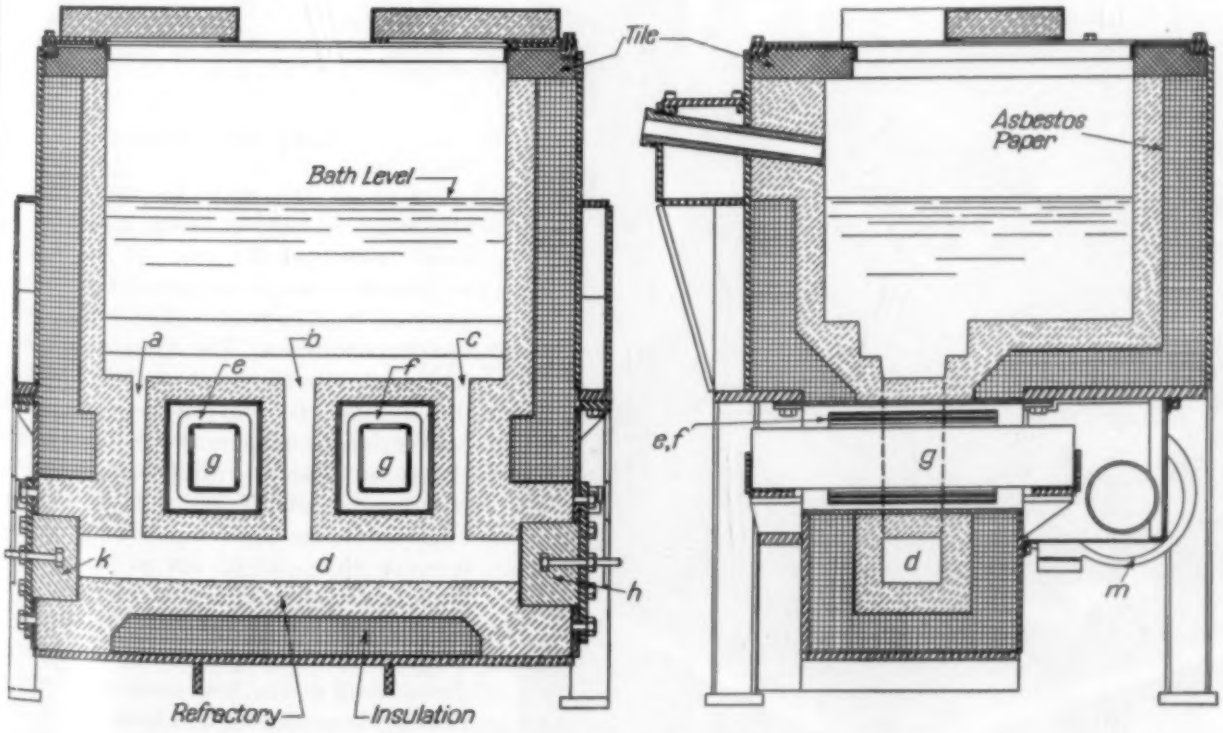


Fig. 2 — Principal Vertical Sections of Induction Furnace for Aluminum

metallic matter so as to insure a constant resistance to the flow of the secondary current. Inclusions of non-conductive slag matter tend to increase the secondary resistance and finally to stop the furnace.

During the last ten years some furnaces were constructed in Europe for melting aluminum alloys; special tools had to be used from time to time to clean the melting channels. This operation required emptying the furnace completely at intervals ranging from 8 to 24 hr., and cleaning the channels with flexible chains or similar tools while the lining was hot. Obviously, this interrupted the melting process and it was impossible to recommend such furnaces to the production-minded American industry. Therefore, a complete new design was developed, avoiding stoppages for cleaning. General cross sections of this furnace along principal vertical planes are shown in Fig. 2.

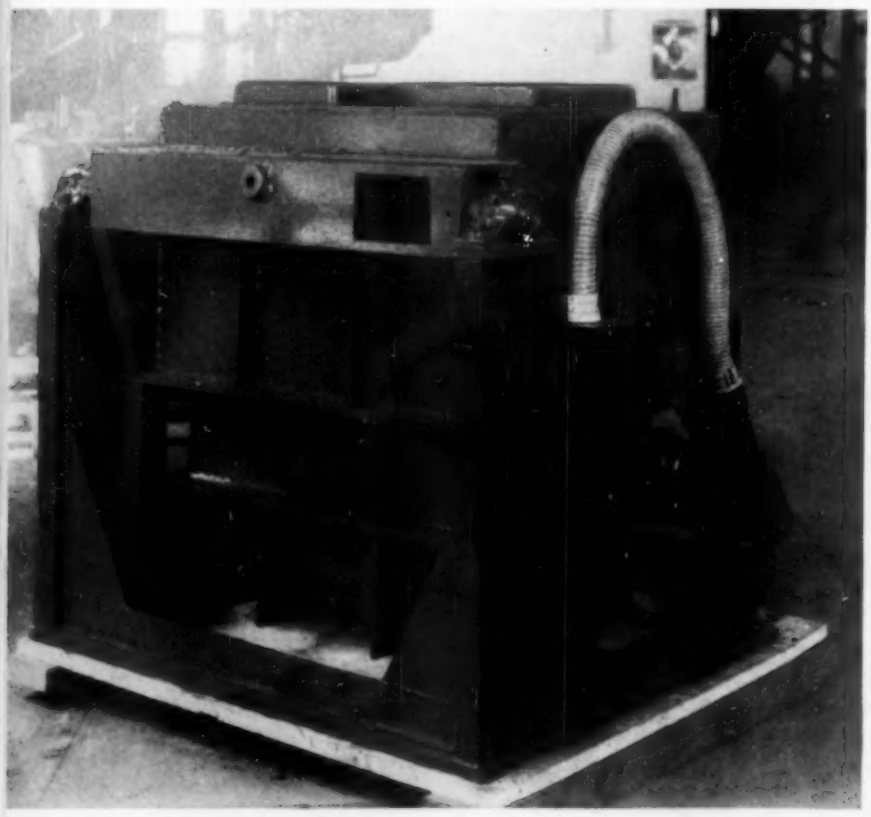
The secondary of this furnace consists of three straight, vertical channels *a*, *b*, and *c*, connected at the bottom by a straight chamber *d* of larger cross section. The two loops, formed by the central leg *b* with each of the outside legs *a* and *c* and with the corresponding part of the bottom channel *d*, are interlaced with two primary coils, *e* and *f*, wound around a closed core *g* of laminated steel. The two coils *e* and *f* are connected to a source of single-phase alternating current.

With this new arrangement of the secondary circuit, the melting channels are maintained clean over long operating periods. Only as a matter of safety, two plugs, *h* and *k*, have been provided at both ends of the straight horizontal channel *d*. These plugs, which are ordinarily sealed with refractory cement, can be opened at intervals ranging from three to four weeks or longer, to inspect the bottom channel and, if necessary, remove any slag which may have accumulated there.

The hearth of the furnace is located on top of the melting channels and the approximate level of the molten bath is shown. Cooling air is circulated along the copper coils by means of two pressure blowers *m*.

Figure 3 shows a photograph of the furnace just described, which is powered with 60 kw., produces around 300 lb. of aluminum alloy per hr., and has over-all dimensions of 39 in. in length, 36 in. in width and 40 in. in height. Furnaces of this type are in continuous 24-hr. operation in prominent mechanized foundries in the United States.

Fig. 3 — Small Induction Furnace in Shop. Capacity 300 lb. melted per hr., holding capacity 500 lb., power rating 60 kw.



At present, three standard types of furnaces with the following characteristics have been made:

Power Rating	Hourly Production	Holding Capacity
60 kw.	300 lb.	500 lb.
125	625	1250
250	1250	2500

Gas Absorption

One of the evils to which molten aluminum is subject is the absorption of gases, chiefly hydrogen. A number of articles have been written on this subject, as cited in Edwards, Frary and Jeffries' standard book on "The Aluminum Industry", and even in the present-day publications, there is scarcely one about the melting of aluminum alloys in which gas absorption is not mentioned. Electric melting, especially in the induction furnace, excludes hydrogen completely, because this gas is not present in the furnace atmosphere above the metal bath. Another source of hydrogen, moist air, is inoperative because water vapor cannot be dissociated at the low temperatures prevailing above the molten bath, below 950° F. The induction furnace is decidedly a

"cold-top" furnace, which is ideal for preventing gas absorption.

Another feature inherent to induction furnaces is the constant and automatic stirring of the melt. The bath is kept in constant movement due to electromagnetic forces, created by the heavy current passing through the melting channels.

In reverberatory furnaces, "fluxing" with chlorine gas is resorted to for removing gas absorbed during the melting period. (This was invented by D. R. Tullis, and first described by him in the *Journal* of the British Institute of Metals in 1928.) The chlorine acts chiefly as a mechanical means of circulating the bath and expelling gas bubbles to the surface. The automatic stirring of the induction furnace acts in the same way, but more effectively, because it is present during the entire melting operation. Repeated tests have shown beyond any doubt that melts made in electric induction furnaces, if properly treated, are free from gas absorption.

The automatic movement of the melt has another advantage, namely, that the entire volume of metal in the hearth of an induction furnace must necessarily be of uniform composition. Also, metals of high melting point, such as copper, nickel, silicon, iron, and others, are easily dissolved at the temperatures given by the respective constitution diagrams.

Foundry Layout

It is recommended that induction furnaces be installed in aluminum foundries in the same way as in large brass foundries. A British casting shop contains a battery of 12 aluminum induction furnaces in a row, mounted alongside a charging platform, to which the individual charges are brought by monorail from the metal storage. All the electric equipment is assembled in a room below the charging platform, and the furnaces are emptied through ladles or into billet molds.

In the United States, billets of large size are usually cast by the Ennor direct casting process. Inasmuch as this requires a very slow rate of pouring, it is recommended that melting furnaces be emptied into a holding ladle provided with an induction heating unit at the bottom, so that the melting furnace can be discharged in a short time and be ready for another charge.

Precision of Pyrometers

AN ERROR crept into bit entitled "Precision of Pyrometers", by METALLURGICUS, page 617 of the October 1943 issue of *Metal Progress*. In the last paragraph pertaining to the heat treatment of the high strength aluminum alloy 24S, these statements appear: "For 24S, for example, a range of 910 to 930° is stipulated. One may suspect that if highly accurate temperature control were employed, the upper limit could be set at 950°."

The heat treating range for 24S has been carefully selected. If the temperature is below the minimum specified, there is the danger that the mechanical properties will fall below those required. If the temperature exceeds the maximum it is possible that some melting will occur in the material. This may cause severe blistering during treatment and may even cause severe cracking on quenching. The initial melting temperature varies slightly from lot to lot, the maximum and minimum observed temperatures being 939 $\pm$ 1° F. and 935 $\pm$ 1° F. respectively. If we consider that $\pm$ 5° at 1000° F. is reasonably accurate for a commercial temperature measuring system, as suggested in the article, then no upward change could be made in the present maximum heat treating limit for 24S. Under no circumstances could the upper limit be set as high as 950° F. (L. A. WILLEY, Research Metallurgist, Aluminum Research Laboratories)

Precision of Temperatures in Heat Treating

LAST MONTH it was remarked that precision in heating involved *(a)* precise temperature measurement — and that was discussed briefly — and *(b)* accuracy with which a precise measuring system is applied.

Let us now consider the second phase of the matter, for the great source of error in temperature measurements in heat treating lies in this factor; all too frequently the pyrometer system does a careful job of truly reporting a temperature which is *not* that of the work-piece!

This is common in radiant-heated furnaces; the couple is often so placed that it tells us the temperature of the furnace walls or else it reports

how it is affected by a burner flame or a nearby resistor. This is a major reason why furnaces with recirculating atmospheres usually give a more uniform product; the control temperature is more nearly the true temperature of the work piece (assuming that the work is kept in the furnace long enough to come to heat).

Salt baths likewise lend themselves to more precise indication of the work temperature.

Consider, for example, a gas-fired box furnace into which a cold charge is put. If the thermocouple is close to the cold work, heat is called for at a high rate; the burners come on and stay on until the steel near the couple comes to heat; in the meantime any work nearer the burners will be overheated. For example, if the thermocouple were placed in the center of a large pile of forgings to be heated to 1500° and the burner flame is capable of heating to 2500°, by the time the thermocouple at the center of the charge gets to 1500° the outside pieces, nearer the burners, may reach 1800° or more. On the other hand, the couple may be placed well up in the furnace chamber so it reports the temperature of the furnace walls; the burners will then be controlled to hold the walls at 1500°, and the work won't be so likely to overheat, but it will heat slower than in the previous case, because the temperature gradients are less.

For this reason, through furnaces with two or more zones of control may be operated to take advantage of the two types of temperature indication: The heating zone, full of cold work, can have the couple near the work so as to call on the burners for a lot of heat, and produce fastest heating. The soaking zone, however, will be controlled by a couple reflecting the temperature of the furnace walls, so that overheating will not occur.

In any furnace the proper locations of thermocouples are not quickly found. Drafts, cold spots, hot spots and the like must be watched for.

We must always remember that a thermocouple is sensitive to heat regardless of source, and the super-couple which will show only the temperature of the steel, in all its parts, won't be available till after the war. Multiple couples, with one doing the controlling and the rest merely watching for over-heating or under-heating, are necessary on large furnaces and heavy loads.

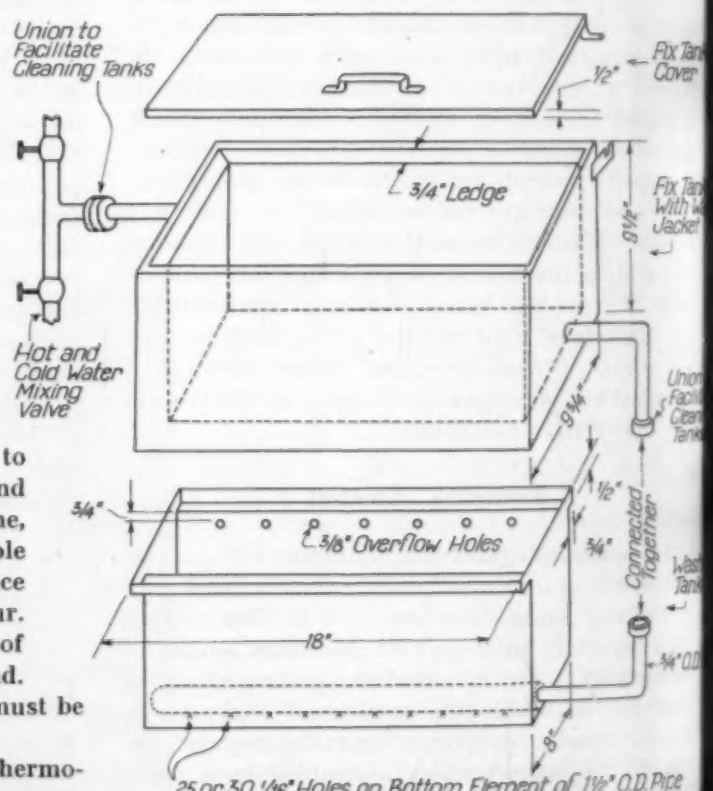
Placing thermocouples so they accurately report the work and prevent radical departure from the desired temperature is the fundamental requirement for accurate control of heat treating temperatures. Carelessness in this matter can cause far more trouble than wide tolerances in temperature ranges for various operations.

METALLURGICUS

Time Saver in Dark Room

R. E. CRAMER'S letter in "Bits and Pieces" of July *Metal Progress* under the above title reminds us of a set-up we were forced to design for our darkroom. It is a fix and wash tank connected together, one in front of the other, set inside and at one end of a soapstone sink.

Cold water enters at the left top of the fix tank water jacket and leaves at the bottom right. Then the water flows in at the bottom right of the wash tank and is forced towards the bottom of the tank through holes in the pipe. The water then overflows from the top.



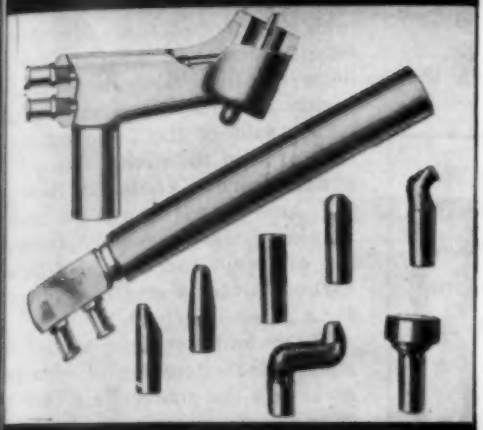
Set of Water Cooled Fix Tank and Wash Tank For Plate Holders Up to 5 by 7 In.

The piping has unions so that the set-up may be disconnected and cleaned easily. Tanks are welded of $\frac{1}{16}$-in. steel sheet. The set-up was designed for 5 by 7, 4 by 5, and 3¼ by 4¼ plate holders. (H. M. SHANNON, Research Dept., Phelps Dodge Copper Products Corp.)

P. R. MALLORY & CO. Inc.

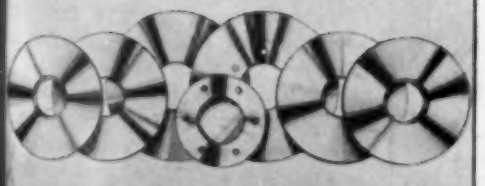
MALLORY

STANDARDIZED RESISTANCE WELDING ELECTRODES



SPOT WELDING TIPS AND HOLDERS

FLASH, BUTT, PROJECTION WELDING DIES



SEAM WELDING ROLLS

Speedier Production
Less Down Time
Better Welding
Lower Cost

Why Electrode Contour Counts

Correct design of a resistance welding electrode is important for several reasons. Whether tip or wheel or die, the electrode is a vital part of any resistance welding machine. It conducts current to the weld, and its shape and size determines current density in the material being welded. Also, the electrode must carry all the pressure needed for a sound weld. It must control the size of weld desired. It must conduct heat away from the outer surfaces of the weld . . . to prevent melting of the surface metal.

In spot welding aluminum alloys for aircraft parts . . . as one example . . . modern electrode design speeds output. For some years spot welding tips with a 7° conical nose have been favored. Today, although some fabricators still use this contour, radius faced tips with a radius of from 2″ to 10″ . . . depending on the thickness of sheets being welded . . . have been shown to produce sounder and more consistent welds. Also, radius faced tips are easily cleaned by hand, using abrasive paper.

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Theory

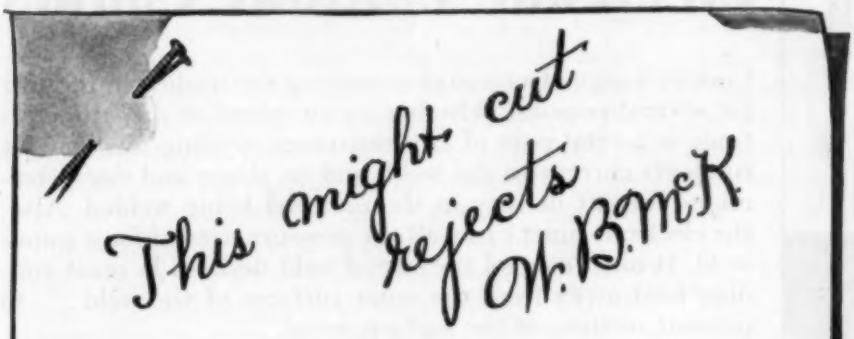
(Cont. from p. 957) Corroboration in the form of hardness data was presented. Your reporter is applying now for a ringside seat for the day when the argument is to be resumed and, possibly, settled.

This session expanded in scope as **Morkovin** reviewed the Russian literature showing yield strength to increase with decreasing temperature, until it reached a maximum value. At and below this temperature brittle fracture occurs at a stress essentially independent of temperature and rate of straining. Hence Morkovin suggests the possibility of direct measurements of cohesive strength by low temperature testing techniques. **Jackson** reported calculations on strain in notched bar testing by considering the deviation from the elastic condition when slight plastic deformation occurs, and **Hollomon** expanded the concept of "equivalent strain rate" mentioned above.

In various other sessions the effects of many variables on flow phenomena were considered. **Parker** enlarged on the concept of an equicohesive temperature. **Hollomon** and **Zener** reviewed the literature on the effect of strain rate and predicted from the available data that in mild steel the yield strength becomes equal to the tensile strength in the range of 1 to 10^5 in. per in. per sec. **Hollomon** presented true stress-strain curves for steels of three different carbon contents each heat treated to a series of different structures. Each curve is described by its slope in the plastic region and the stress intercept at zero strain of the prolongation of the curve in the plastic region. For a fixed carbon content with varying heat treatment, the slope increases along a smooth curve as the intercept increases, but higher carbon contents give higher slopes for a given intercept.

Lacy and **Gensamer** studied the effect of 11 common alloying elements on the stress-strain curve of pure binary alloys with iron. They showed that the logarithm of the increase in tensile strength of ferrite is a straight line function of the logarithm of the atomic per cent of alloying element present. Beryllium stands well at the head of the list and, if considered in terms of weight per cent, is a phenomenal ferrite strengthener. The strengthening effects of several elements in solution together were shown to be additive. **Low** and **Gensamer** showed that the yield point, strain-aging, and quench aging may all be eliminated from low carbon steels by annealing in wet hydrogen at 1300° F. (700° C.). It was shown that these phenomena are caused by small amounts of carbon or nitrogen (as little as 0.003% of either), that they return upon carburizing or nitriding a "stable" specimen, and that oxygen, *per se*, is not responsible for the phenomena.

Other papers recommended to those interested in plastic deformation include a study of preferred orientation in low carbon deep drawing steel by **Stanley**, a study of dimensional changes during tube sinking by **Baldwin** and **Howald** and a pair of contributions by **Sachs** and co-workers. One of these deals with the effect of heat treatment and test conditions on the tensile strength of steel bolts; the other is an exhaustive study of the effect of test conditions on the strength of notched tensile specimens of heat treated steels.



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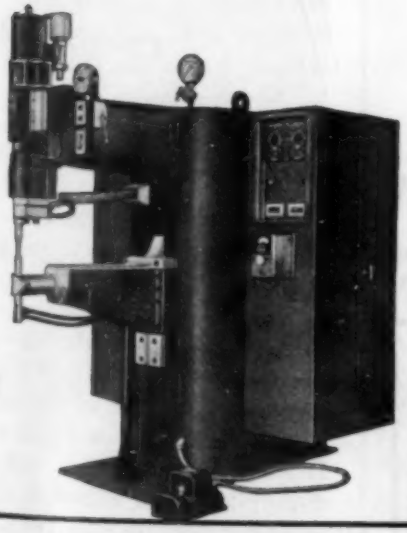

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Tensile Impact

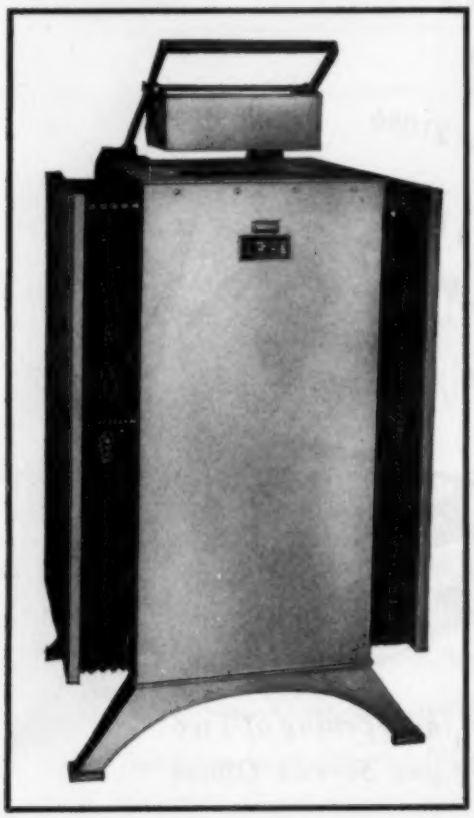
(Continued from page 937) strain curve. Results are as given in the table.

"There was no difference in the percentage reduction of area in the static and single-shock or impact tests. There was no appreciable difference in the nature or appearance of the fractures of the corresponding specimens ruptured by single-shock and by static means when examined by the naked eye," in the words of the authors.

Steel	Rupture Energy		Elongation		Tensile
	Static	Shock	Static	Shock	Strength
0.12% C	550 ft-lb.	538	26.0%	24.3%	54,300 psi
0.18	616	529	24.9	23.5	60,300
0.28	708	598	19.7	18.2	75,000
0.29	674	546	20.5	19.7	78,000
0.33	663	574	21.0	20.3	76,600
0.37	723	557	19.0	17.6	86,000
0.47	672	568	16.4	16.7	92,000
0.52	688	561	15.9	15.5	99,500
0.58	571	522	11.5	12.1	113,500
0.63	550	517	11.5	11.3	117,000

Summation of the ener absorbed in repeated blows (to energy for rupture) rises ve fast as the number increases light blows required to fractu For example, for the 0.33 carbon steel: A single fall fro 80 in. will break the specim (which absorbs 574 ft-lb. energy thereby). Nineteen dro of 9 in. are required to bre another specimen from the sa bar, which absorbs 1196 ft-lb. energy meanwhile. If the dr is reduced to 2 in., 764 shoc are required and the energy f rupture totals 10,700 in-lb. Th and other evidence indicates th an "endurance limit" might reached for each material und these conditions; "it seems, ho ever, that conclusive evidence, the same nature as that in exi ence for gradually applied stre fatigue limits, is still lacking

Another point is worthy mention: The tabular figur show that the rupture energy single shock is substantial independent of carbon conte and tensile strength of the ste If the drops are adjusted cause failure after 100 shoc the necessary height of dr increases regularly from 2 in. 7 in., or 3½-fold, as the carb content of the steel increas from 0.12 to 0.63%. (Tot energy absorbed increases in t same proportion.) Likewise, the drops are adjusted to cau failure after 1000 shocks t height of drop increases fro 1 in. to 3.5 in. (also 3½-fold) the carbon content increas from 0.12 to 0.63%.



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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Automatic profilers and hydraulic benders are described in catalogs issued by the Pines Engineering Co. Bulletin 344.

Clark 3-blade adjustable hole cutter and 3-blade adjustable surface facer are described in new illustrated leaflet by Robert H. Clark Co. Bulletin 348.

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin 6.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties, applications and use of hard-facing rods. Coast Metals, Inc. Bulletin 249.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Handbook on aircraft riveting. Cherry Rivet Company. Bulletin 14.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools, shows prices of tools and blanks. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Parsons oval bag dust arrestors are described and 12 advantages listed in folder issued by Parsons Engineering Corp. Important advantage is reclamation of valuable dust. Bulletin 228.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

FERROUS METALS

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Machinery steel selector has been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin 256.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 24.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Chemical analyses, shapes and sizes of Joslyn stainless steel products are presented in extras and deductions booklet just issued by Joslyn Mfg. and Supply Co. Bulletin 297.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

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1	33	60	89	114	141	165	188	213	255	296	325	347	368
2	35	62	91	115	142	167	189	215	256	297	327	348	369
3	38	64	93	116	143	168	190	217	258	298	328	350	371
4	40	65	94	117	144	169	192	221	260	299	329	351	372
5	41	66	95	118	146	170	193	226	261	300	330	352	374
6	42	67	96	119	147	171	194	228	264	301	331	353	375
7	43	68	97	120	148	172	196	230	267	305	332	354	376
8	44	70	98	121	149	173	197	232	268	307	333	355	377
10	45	71	99	122	150	174	199	233	269	312	334	356	378
12	47	72	100	123	152	175	200	234	270	313	335	357	379
14	48	75	101	124	153	176	201	240	271	314	337	358	380
15	49	76	102	128	154	177	202	241	276	315	338	359	381
20	50	78	103	132	155	179	203	242	277	316	339	360	382
21	51	79	105	133	156	180	204	243	281	318	340	361	383
24	52	82	106	134	158	182	206	245	284	319	341	362	384
25	53	83	107	135	160	183	207	246	288	320	342	363	385
26	54	84	108	137	161	184	208	249	290	321	343	364	
29	56	85	109	138	162	185	209	250	291	322	344	365	
30	57	86	110	139	163	186	210	251	292	323	345	366	
31	59	88	112	140	164	187	212	252	294	324	346	367	

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Low carbon open hearth case carburizing steel. W. J. Holliday & Co. Bulletin 38.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

New handbook on when, where, how and why to use various types of stainless steel is offered by Rustless Iron and Steel Corp. Bulletin 334.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

Engineering and comparative information on porcelain enameled iron is presented in new illustrated booklet by American Rolling Mill Co. Bulletin 376.

Attractive, illustrated 64-page booklet describes the welding of stainless steels. Allegheny Ludlum Steel Corp. Bulletin 384.

NON-FERROUS METALS

Reynolds Metals Co. has issued two color charts showing marking for identification of wrought aluminum alloy products, rod, bar, tubing and shapes, and for aluminum alloy sheet. Bulletin 294.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Bronze. Frontier Bronze Corp. Bulletin 44.

Copper Alloys. American Brass Co. Bulletin 45.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin 47.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin 50.

"The Story of Magnesium," illustrated booklet by the Permanente Metals Corp. Bulletin 261.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin 53.

Surface protection for magnesium. American Magnesium Corp. Bulletin 54.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

WELDING

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Flexarc A-C welders. Westinghouse Electric & Mfg. Co. Bulletin 64.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Shield Arc electrodes. McKay Co. Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

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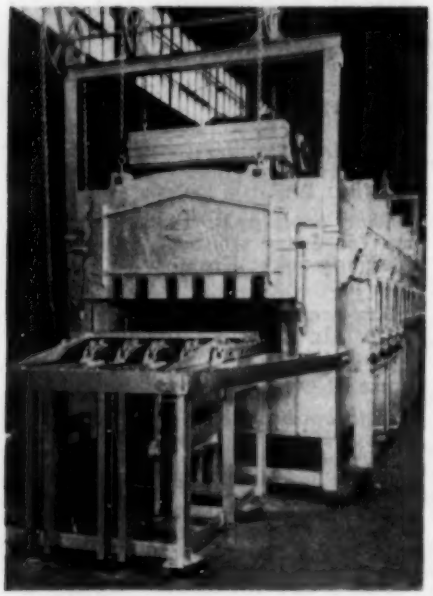

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New JR shape cutting machine is described by National Cylinder Gas Co. Bulletin 233.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

New "200" welder is described by Allis-Chalmers in Bulletin 260.

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 241.

Welding alloys and metals on which they should be used are shown in helpful chart form by Eutectic Welding Alloys Co. Bulletin 242.

32-page catalog describes line of welding equipment offered by Victor Equipment Co. Bulletin 245.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin 251.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin 29.

New 500 lb. capacity welding positioner for light welding jobs is described by Ransome Machinery Co. Bulletin 313.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

New line of welding positioners with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

TESTING & INSPECTION

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

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Data Sheet

Subject: Practical Application of Induction Heating Principles — Part 4 **Sheet No. 7**

THROUGH HEATING BY ELECTRICAL INDUCTION

Any of the discussions of induction heating thus far should not be construed as indicating that the resultant heat pattern is solely a surface phenomenon. While it is true that all the electrical energy is transformed to heat energy at the surface of the metal undergoing a temperature rise, and the degree of this surface effect increases with the frequency of the electrical current, this factor is only one of many going to produce the final heat pattern within the objective metal. First let us consider heat conduction between adjacent molecules of metal. We have already shown that the outermost layer is first heated and this layer may vary from 0.050" down to 0.003", which are the effective values for the common frequency ranges. As soon as this outer layer rises in temperature, the next inner adjacent layer draws heat energy from the outer layer by conduction. The rate of heat transfer between adjacent layers depends upon the physical characteristics of the particular metal in question, but all metals have relatively high rates of heat transfer with respect to other materials.

This conduction of heat to the next innermost layer is a progressive function and results in a definite temperature gradient across the material. The steepness of this gradient is in turn dependent on the relative rates of energy input to the heat-generating layer and the conductivity of the material. Hence it is evident that any desired gradient can be obtained by manipulation of the rate of energy input since this is the only variable, inasmuch as the heat conductivity is determined by the physical characteristics of the metal. In the case of surface hardening, the input rate is maintained as high as possible in order to confine the heat to the outer surface and remove it by quenching before it has had an opportunity to be conducted into the inner layers. To effect this in practice, however, would require infinitesimal heating times which in turn demand large energy input per square inch of surface. Since the watts per square inch (power per unit area) is limited by various factors discussed previously, this is not possible, and the resultant heat pattern, regardless of power input, never confines itself to the heat-generating layer. Maximum power per unit area show results of maximum heat penetration of approximately 0.03125" (1/32") with a heat-generating layer of about 0.005".

Let us turn now the other way and see how flat a temperature gradient can be obtained, which is the desired result in through heating, as compared with the steep gradient mandatory in surface heating. Here the energy input rate to the heat-generating layer should be as low as possible to still cause the mass being heated to undergo a temperature rise. The radiation losses from the surface of the work are now the governing factor and must be considered, instead of the conduction as in the case of surface heating. The total heat generated in the work is used up in two ways; first, as energy to raise the temperature of the mass itself, and second, in heat lost principally by radiation. When this latter quantity equals in rate the energy input, the temperature of the mass no longer rises, since these radiation losses are a function of the temperature (actually t^4 which makes it extremely critical).

From this, it can be seen that a given mass of metal, with a fixed shape, will have a definite radiation loss for every temperature, and this is the criterion for design in induction "through heating". The rate of energy input is a function, among other things, of the flux density of the magnetic field, and this quantity, in reiteration, is a function of current and the distance between the current-carrying conductor and the work. Hence, to control the energy input to the work, the current can be decreased and the spacing increased. The first of these is best accomplished by making a number of coils in series electrically and thus decrease the current by increasing the electrical impedance of the circuit. This method utilizes the full power output of the electrical source, which would not be the case if the current to a single coil was decreased by other means. The spacing between the work and coil is simply a matter of coil design and is best determined by experimentation.

In summation, it is seen that the desired through heating is obtained by decreasing the total power input to the work to a value slightly greater than the radiation losses at the desired temperature. This is done by passing less current through the coils, preferably by placing a number of coils in series and heating a number of pieces simultaneously, and is further controlled by widening the spacing between the work and the coil, or, in usual terminology, "loosening the coupling".

Through heating is desired in industrial applications for two specific problems; through hardening and forging. In the case of through hardening, the coil and work-holding fixtures are so designed to allow quenching following the heating cycle, either by immersion in the quenching medium, or by spraying the quenching medium on the work while it is still in the coil. The specific type of quench depends on the metal being treated, its shape, and other factors already discussed under surface hardening. The method is characterized by a relatively slow "soaking" heat rather than by the rapid heating cycle usually common to induction heating practice. This slow heat causes considerably more scale and oxidation, and hence does not give the clean scale-free surface so often found with the induction method of heating.

Probably more predominant in the induction "through-heating" applications are those for forging, where the temperature of the metal is to be raised to give it the proper physical characteristics for forming, or "hot working". Its advantage for this work lies in its short heating cycle in comparison to furnace methods, and the resultant lack of scale which is abrasive and contributes greatly to the deterioration of forging dies. This may seem contrary to the discussion on scale during "through hardening", but the relative heating cycles between induction "surface-hardening" and induction "through-hardening" are both extremely short compared to furnace heating cycles common to forging operations.

Induction heating set-ups for forging operations are usually arranged so the operator can place the work in the coil with a minimum of effort and easily and rapidly remove it for the actual forging work. Automatic feeding devices can be arranged in many cases, where the heated pieces are delivered periodically by means of a conveyor to the press operator. Such arrangements eliminate the human element and insure the operator of a piece at the correct temperature being delivered at periods synchronized with the press speed.

Hence it is seen that induction heating can be used for "through heating", for "through hardening" and forging, and while this type of heating is not near as spectacular in result as "surface heating", it still deserves an important place in the list of the many contributions to industry made by electrical induction heating.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Precision production tools such as surface plates, angle plates, straight edges, etc., are described in Catalog No. 42 issued by Acme Tool Co. Bulletin 340.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Electric heaters and controls for industrial and laboratory. American Instrument Co. Bulletin 75.

Carbon-Meter for rapidly determining carbon at the furnace. E. Leitz, Inc. Bulletin 264.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Surface Analyzer. Brush Development Company. Bulletin 88.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Identometer for rapid identification of steel. Dravo Corp. Bulletin 267.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

Eberbach micro hardness tester is illustrated and described in new booklet by Eberbach & Son Co. Bulletin 269.

Moisture determinations of a wide range of materials with new Moisture Teller instrument are described in new leaflet by Harry W. Dietert Co. Bulletin 299.

New flexible film holder for industrial radiography is illustrated and described in leaflet by Picker X-Ray Corp. Bulletin 300.

Stresscoat, a method of analyzing distribution, direction and value of local strains in any structure by means of formation of characteristic crack patterns in a brittle coating applied to its structure, is described in leaflets issued by Magnaflux Corp. Bulletin 301.

Two new folders describe Searchray 80, new self-contained X-ray unit of North American Philips Co. Bulletin 377.

TEMPERATURE CONTROL

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

40-page booklet contains useful technical information on thermometry and thermometers. Bristol Co. Bulletin 321.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

New file folder service bulletin on Weaver Furnace Atmosphere Indicator. Claud S. Gordon Co. Bulletin 332.

New condensed catalog gives prices and descriptions of instruments offered by Wheelco Instruments Co. Bulletin 268.

Use Handy Coupon on Page 994 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 994, 995, 996, 1000, 1002, 1004, 1006, 1008, 1010, 1012 and 1014.

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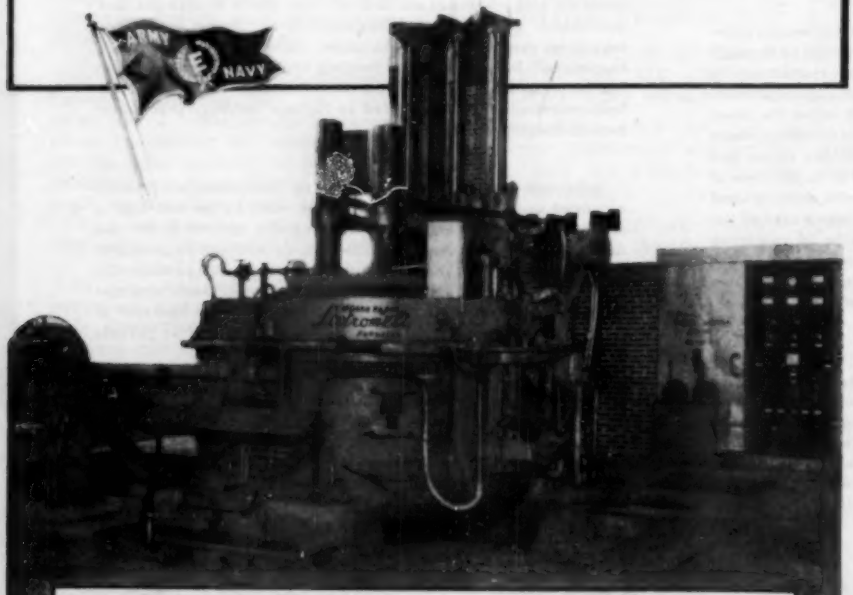

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IN MANUFACTURERS' LITERATURE

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

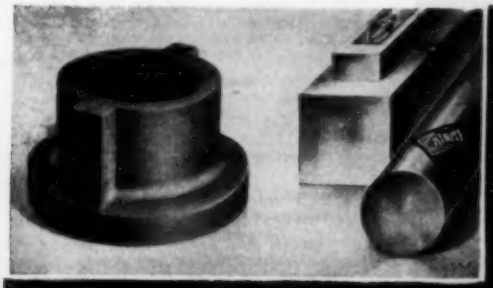
Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

New leaflet describes valve operator of industrial operation of valves, dampers and other control devices. Automatic Temperature Control Co. Bulletin 381.

HEATING • HEAT TREATMENT

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin 99.

Induction heating. Induction Heating Corp. Bulletin 103.



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Internally heated salt bath furnace and pots. Upton Electric Furnace Div. Bulletin 102.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin 105.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Hagan rotary forging furnaces are described in bulletin by George J. Hagan Co. Bulletin 108.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Homo method for nitriding is described and illustrated in new 16-page catalog by Leeds & Northrup. Bulletin 100.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Centrifugal blowers and exhausters. Roots Connersville Blower Corp. Bulletin 270.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin 290.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin 120.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin 121.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Tocco hardening, brazing, annealing and heating machines. Ohio Crankshaft Co. Bulletin 124.

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